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FERDINAND, FREIHERR VON RICHTHOFEN

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Ferdinand von Richthofen is best known in the countries other than his fatherland as the explorer of China, and the author of the theory of the origin of the eolian loess deposits. In Germany his dominant personality carried his influence into many affairs not immediately connected with the sciences of geography and geology, in which he was a specialist. In him the emperor has lost a well-informed and conservative counselor.

Von Richthofen first took up geological work in connection with the *Wiener Reichsanstalt* in 1856, at the age of twenty-three. His earliest publications relate to the structure of the Tyrolean Alps, and the occurrence of certain igneous rocks. In 1860 he was appointed attaché for scientific studies with the Prussian expedition of Graf von Eulenberg to China, a diplomatic mission reinforced by four men-of-war, its object being to persuade the Chinese to enter into treaties with the German powers. Two years passed in diplomatic negotiations, during which the eager explorer found little opportunity to penetrate beyond the coast line of the unknown land; but he availed himself of a voyage made by one of the frigates among the East India islands to visit Formosa, the Philippines, Celebes, and Java. He also made excursions into Siam and farther India.

When the embassy returned, von Richthofen remained in the East, in accordance with the original resolution with which he had left Europe, to solve some problem of broad bearing with reference to the Asiatic continent. His early plans were thwarted, and he finally made a voyage to San Francisco, whence he extended his travels through California and Nevada. Years had passed since he left home, and his original purpose remained unaccomplished, but unshaken, when on New Year's, 1867–68, he discussed with Professor J. D. Whitney those regions of the world of which geological studies were most needed. They agreed that China was, in view of its civilized state and general relations, the land which promised the richest results, and, in spite of the gigantic dimensions of the problem, von Richthofen determined to devote his energies to a study of that country for a number of years. He proposed to himself to explore, with individual resources, a land one-third larger than the United States, of which there were no maps more useful than rude Chinese sketches, and regarding which there was no scientific literature. Although China had been traversed by missionaries for centuries, and in the beginning of the eighteenth century the Jesuit fathers had determined the astronomical positions of nearly all the principal cities of the empire, our ideas of its geography were still an assemblage of myths. The conditions of investigation among a superstitious and unfriendly people, of whose language he was ignorant, might well, even under ordinary circumstances, have deterred the explorer, and they were at this time peculiarly unfavorable in consequence of the Tai-ping rebellion, and of the Mohammedan rebellion in the northwest provinces. Casting about for a companion, who might act as servant and interpreter, von Richthofen found it impossible to secure a Chinese of sufficient education who would submit to the hardships of such a journey as he proposed. There was at the moment in Shanghai a Belgian, Paul Splingaert, who, having killed a Chinese, was on trial and liable to sentence of death. Von Richthofen believed that the act was justified by attendant circumstances, and proposed that the man, who was accomplished in the Chinese dialects, should be released to accompany him. The authorities, being quite willing to yield the responsibility of his execution to some mob of the interior, agreed, and during four years Splingaert was von

Richthofen's constant and loyal companion. Von Richthofen gives him great credit for the success of the expeditions, and no doubt with justice, since the interpreter holds the fate of a party in the hollow of his hand.

With an appropriate sense of caution which, coupled with courage, resolution, and a strict sense of justice, was the basis of his success among the Chinese, von Richthofen made his first journeys by water on the Yang-tzī below Hankow, and the canals and lagoons of its lower course. His third journey was an extended one, by land, through the province of Shan-tung, and it is perhaps not too much to say that during the six weeks he spent there in the spring of 1869 he laid the foundations for the occupation of the peninsula by the Germans, who have developed their enterprises closely along the lines foreshadowed in his geological reports. From Shan-tung he proceeded to the Liau-tung peninsula, which he traversed as far as the borders of Korea, and, returning via Mukden, he reached Peking. The traveler was now reluctantly brought to consider the necessity of returning home, when through the efforts of Mr. Alexander Cunningham, head of the American house of Russell & Co., the Chamber of Commerce at Shanghai became interested in his explorations and undertook to support them. Having made a short trip, which he calls his fourth journey, through Kiang-si and Chö-kiang, von Richthofen began to prepare for the fifth journey, during which he traversed China from south to north, from Canton to Peking, and passed through a number of provinces where the population was believed to be peculiarly inimical to foreigners, and where he was a pioneer. His route from Canton to Hankow, on the Yang-tzī, was that afterward followed by the American engineer, Parsons, and that along which the proposed North-South Trunk Railway of China is to be built. Northward from Hankow he traveled by the Han River to the western margin of the great plains, and thence followed the foothills northward to the Yellow River. After crossing the latter he turned westward into the mountainous province of Shan-si, the province of great coal resources, and pursued thence the imperial highway to Peking. This journey occupied five months, from January to May, 1870. It was an enterprise of the highest daring, and one which yielded a rich treasure of observations in geography, geology, and the natural resources of the country.

Within three weeks of his arrival in Peking von Richthofen was prepared to undertake a still greater journey than the last, into the far southwestern provinces of China, but the massacre of Tientsin checked his plans, and, receiving news of the war between France and Germany, he was again about to return home. He realized, however, that he must arrive too late to be of material service to his country, and finally decided on a journey in Japan, where he became intensely interested in the varied features of that delightful little country. He says:

> I parted from it with regret, and yet I returned with joy to my work in China. For only after I had realized the smallness of the features of that land [Japan] did I become aware of the greatness with which every problem is presented in China. China lacks all of those charms which delight the traveler in Japan. One's mood becomes earnest, the conditions of life are unpleasant, but one's view is widened, and gigantic problems rise before us, of equal importance for the past, the present, and the future.

In this expression we have a suggestion of the spirit of the man, who had early set himself a task beyond the strength of most men, and who rejoiced as he realized its immensity.

His sixth journey in China was undertaken to fill out the months until the climatic conditions should be favorable for the trip to the far western provinces, and was an excursion which occupied some weeks in midsummer, 1871. Late in October he left Peking for his greatest and last journey through northern China, Mongolia, and central China, to the heart of Ssī-ch'uan. His intention of proceeding to Thibet was there thwarted, and, being near the end of his ready money and remote from any point at which he could replenish his purse, he was obliged to return, via the Yang-tzī River, along the route followed a score of years earlier by Abbé Huc.

In December, 1872, after an absence of twelve years, von Richthofen returned to Germany. In 1873 he was elected president of the Geographical Society of Berlin, an office which he also held from 1903 to the time of his death. During the years 1879–83 he was professor of geology at the University of Bonn. From 1883 to 1886 he was professor of geology and physical geography at the University of Leipzig, and in 1886 became professor at the University of Berlin. He was director of the Geographical *Anstalt*, and of the *Museum für*

Meereskunde; and 1903–04, rector of the University of Berlin, a position of honor conferred only upon the most distinguished.

Von Richthofen's scientific activity covered half a century, we may almost say the half-century of geological progress. He himself never stood still, but, advancing, welcomed newly discovered facts, was receptive to fresh ideas. In a letter received from him shortly before his death, he writes:

> Die Anschauungen wandeln sich; die Art, die Dinge zu sehen und zu beurtheilen wird eine andere, bei der Allgemeinheit und bei dem Einzelnen.

And, referring to recent investigations in parts of China which he had described, he says:

> Niemand wird mehr Freude daran haben als ich selbst, auch wo sie mich berichtigen und ergänzen. Ich begrüsse diese Berichtigungen, welche 33 bis 34 Jahren nach meiner einsamen Wanderung in dem damals noch verschlossenen Land gemacht werden.

His contributions to science are characterized by the qualities which distinguish him as an explorer of unknown lands: capacity for painstaking and detailed observation, combined with a broad grasp of his subject, and a daring conception of ideas. His ability to observe and to present his observations in a striking manner is exemplified in his reports on the geology of the Tyrolean Alps, which were written before he was twenty-seven. They are important works, illustrated with many studies of intricate structure, and they show a thorough comprehension of the best methods of geological study and presentation. These methods reappear in his great work, *China.* Upon the internal literary evidence it would be easy to determine that the early papers and the later volumes were written by one and the same hand, even though the name of the author had remained unknown.

Volumes I and II of *China* are by himself; the first deals with the geography of China and central Asia, and presents initially a description of the regions from the standpoint of our knowledge at the time it was written, 1873–76, and, secondly, an account of the development of intercourse between Europe and China since the legendary period of 1122 B. C. The latter subject is discussed through study of Chinese works, of which von Richthofen made extensive use. The book also contains the discussion of the loess,

its characteristics and mode of formation. Volume II of *China* is the statement of his observations in the northern provinces, together with the systematic treatment of the material according to geological systems and periods.

Volume III, which was to contain a similar discussion of his observations in the southern provinces, and which would, no doubt, have presented, in a revised form, his views on the systematic questions involved, remains unfinished. Volume IV, "Paleontologie," prepared by the specialists to whom his collections were referred, appeared in 1883.

Von Richthofen's field-work in China and the principal publication of results fall within the decade 1868–77, contemporaneously with the Fortieth Parallel Survey, and there is much besides the coincidence of period to invite a comparison. Each entered a *terra incognita* marvelously rich in geological facts, displayed on a grand scale; each reaped a magnificent harvest, and that gathered by von Richthofen's individual efforts is worthy of a place beside that of his American colleagues; and each elaborated some theoretical views, which the science has outgrown. But though modern research may find much to correct in their early labors, it owes its opportunity to these pioneers; it should not forget the conditions under which they worked; and it should be prepared for the advance which science is making, always ready to say in the words of von Richthofen: "I welcome these corrections."

There is perhaps no better illustration of von Richthofen's method of attacking a problem than the development of his theory of the loess, of which he has given a full account in his various articles upon the subject. He enumerates the extraordinary conditions of its occurrence in China, which seem to preclude its formation by any of the agencies usually invoked to explain the deposition of sediments, and states that as early as his first journey through Shan-si he conceived the hypothesis of deposition by wind under the climatic and geographic conditions of the steppes of central Asia. His later work upon the subject was directed to critical investigation of the regions in which a similar process is now going on, and he was fortified in his view at every step by the close analogy between the deposits of the desert basins and those of the loess-covered districts. He did not

shrink from attributing to a generally neglected agency, the wind, effects which are not only actually stupendous, but which he himself overestimated. He pursued the phenomena of the loess districts into the minutest details, and found ingenious and consistent explanations for the most puzzling peculiarities. His views were accepted by those who were most familiar with the loess of Asia, and there is no doubt that they must always constitute a principal part of any explanation of the phenomena. If they be modified, it will be through recognition of the fact that great changes have taken place in the mountain and river systems of China during and since the epochs of the loess.

Von Richthofen's latest contributions consist of four papers, entitled: "Geomorphological Studies of Eastern Asia." In these he pursues the method with which, in his earlier work, he boldly sketched the mountain ranges of China far beyond his field of observation, on the basis of the strike of geological formations; but he enlarges his field from orogenic to epeirogenic problems, and discusses the relations of the great highlands of Asia to the lowlands of its eastern coast and the curving chains of islands which inclose the adjacent seas. These problems are closely related to those to which Suess has devoted his life-work in the search for the *Hauptstruktur-Linien* of the earth, and they are intimately connected with fundamental questions of continental equilibrium and volcanic eruption. The articles are the fruit of the broadest knowledge of the geographical facts and of the most earnest lifelong study of the stupendous phenomena which Asia as a continent presents. They are the last work of the master of the subject.

Von Richthofen was a man of large stature and fine appearance, one who knew well the respect due to scholarship and the dignity of his own position. On occasion his grave courtesy expressed that dignified reserve which marks the deep thinker and the doer of great things. His life had been spent in consideration of large problems not only of science, but of nations and of humanity. His powerful intellect had grown with profound thinking, and in discussion one felt its grasp and penetrating force. But his heart also had grown great with experience, and his natural kindliness led him ever to consider others before himself. He was not only a great man, he was a man to love and honor.

STRUCTURE AND RELATIONSHIPS OF AMERICAN LABYRINTHODONTIDÆ

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The term "Labyrinthodontidæ" is used in this paper with the same signification as Zittel uses it in his *Handbuch der Palaeontologie*. A discussion of the genus *Eryops* is included here because it was studied by the writer for comparison with the Labyrinthodontidæ, and some interesting facts were brought out by this study.

The first remains of Labyrinthodontidæ known from America were discovered by Ebenezer Emmons in the Trias of North Carolina, and were mentioned by him in *The Geological Report of the Midland Counties of North Carolina* in 1856. The same year Leidy described these remains and proposed the generic name *Dictyocephalus* for them.[1] In 1866 Cope described some skull bones from the Trias of Chester County, Pennsylvania, and referred them to the European genus *Mastodonsaurus*.[2] Two years later[3] he founded the genus *Eupelor* on these skull bones and some teeth from the same locality, but the following year referred the teeth to thecodont reptiles.[4] In 1868 he described a skull from the Trias of Chatham County, North Carolina, giving to the genus which it represented the name *Pariostegus*.[5] In the *Report of the United States Geographical Survey West of the 100th Meridian* for 1875 he described some fossils from the Trias of northwestern New Mexico, among which were three sculptured plates that he referred to *Typothorax*, a genus of Parasuchians; but they are without doubt fragments of a labyrinthodont skull. In 1892 the same writer mentions the occurrence of a form allied to *Eupelor* from the Docum Beds of northwestern Texas.[6]

[1] *Proceedings of the Academy of Natural Sciences of Philadelphia*, Vol. VIII, pp. 255, 256.

[2] *Ibid.*, 1866, p. 250. [3] *Ibid.*, 1868, p. 221.

[4] *Transactions of the American Philosophical Society*, Vol. XIV, p. 25.

[5] *Proceedings of the Academy of Natural Sciences of Philadelphia*, 1868, p. 211.

[6] Geological Survey of Texas, *Fourth Annual Report*, pp. 12, 17.

In 1899 Dr. Lester F. Ward collected, among other things, a fragment of a Labyrinthodont cranial plate from the Trias of northeastern Arizona, near Tanners Crossing on the Little Colorado River. The following year Mr. Barnum Brown obtained from the same locality an interclavicle of a large Labyrinthodont which Mr. Lucas described as *Metoposaurus fraasi*.[1]

In 1902 Mr. Newton H. Brown found various Labyrinthodont bones in the Triassic deposits near Lander, Wyoming. He sent some fragments of these to Mr. Lucas, of the National Museum, and others to Professor Knight, of the University of Wyoming. After the death of Professor Knight, the fragments sent to him were forwarded to Professor Merriam, who recently sent them to the University of Chicago. Among them was the back part of a mandible belonging to one of the skulls described in this paper. Mr. Brown very generously gave the benefit of his intimate acquaintance with the Triassic deposits of the Lander region to a University of Chicago party that collected there in 1904, and it has given the writer much pleasure to name the type species of *Anaschisma* in his honor.

In the fall of 1904 Mr. Reed, of the University of Wyoming, sent to the University of Chicago, for examination, some vertebræ and fragments of cranial bones of Labyrinthodonts obtained from the Trias about forty miles south of Laramie, Wyoming. Dr. Williston, in company with Mr. Reed, had visited this locality a few months previously, and ascertained that their horizon is not far from the top of the Red Beds, and provisionally refers it to the Hallopus Beds of Marsh.

SPECIMENS OF LABYRINTHODONTIDÆ FROM THE LANDER REGION

The material collected by the University of Chicago party of 1904 includes vertebræ, fragments of skulls, breast-plates, ribs, and limb bones. All of the vertebræ have the arches broken away. There are more than forty in the collection, but no two are known to belong to the same animal. The skull bones are fragmentary, and the fragments are usually small, though one specimen includes the frontals, prefontals, and nasals. Fragments of breast-plates are

[1] *Proceedings of the U. S. National Museum*, Vol. XXVII, No. 1353, p. 194.

numerous, and are usually of larger size than those of the skull, while two nearly complete clavicles and one interclavicle were obtained. The fragments of ribs and limb bones are small, and are referred to Labyrinthodonts with some doubt.

The best material known is two skulls collected by Mr. Brown from the same locality as that mentioned above. The skulls were found closely associated, one slightly overlapping the other. They represent two species here described as *Anaschisma browni* and *Anaschisma brachygnatha*. For convenience in the general descriptions, the skull of the former species is designated as A, and that of the latter as B.

In A most of the left maxillary, the lower part of the left quadratojugal, the left condyle, part of the posterior end of the parasphenoid, part of the outer end of the right exoccipital, a small portion of the posterior margins of the epiotics and prosquamosals, and the right opisthotic are missing. In B most of the right maxillary, part of the right premaxillary, part of the lachrymals, the condyles, and the upward projections of the exoccipitals are not present. About 8^{cm} of the anterior end of the left mandible of A is broken away. The right mandible of B lacks a part of the anterior and part of the posterior end of the dentary, and also most of the surangular.

The skulls were incased in a hard matrix of arenaceous shale, and had been broken in many pieces. This matrix has been removed in the laboratory with considerable labor, and both skulls now present the outer surface of all of the bones.

The inner surface of most of the bones was examined by the writer, but has necessarily been concealed in the restoration of the skulls. Nearly all of the sutures were distinctly traced either on the inside or on the outside of the bones. The skulls are but little distorted.

Anaschisma, *gen. nov.*

Skull large, subtriangular. Bones of the roof all deeply sculptured. Frontals excluded from orbits by the junction of the pre- and postfrontals; all of the bones behind the orbits, excepting the supraoccipitals and epiotics, elongated; lachrymal forming part of the posterior border of the nares. Opisthotics short, not coalesced with the exoccipitals. Parasphenoid with a long, narrow, cultriform process

anteriorly; exoccipitals meeting in the median line in the floor of the skull. Parietal foramen small, subcircular; no auditory notches; orbits very large, subcircular, situated in anterior half of skull, and widely separated from each other; premaxillary vacuities large, double, penetrating the roof of the skull at the anterior end of the nares; nares terminal, large, ovate. Base of skull with large quadrate foramina; foramen magnum large, with no inward projections of the exoccipitals. Palatine foramina expanded anteriorly. Teeth with labyrinthine structure much like that of *Mastodonsaurus;* a large tooth on each ramus of the mandible near the symphysis. Mandible broad and thin, breadth and thickness as 4 to 1; a strong postcotylar process present.

Skull.—The skull of *Anaschisma* resembles that of *Metoposaurus* and *Capitosaurus* in shape. It is subtriangular, with the margins gently convex anteriorly, gently concave in the middle, and again gently convex posteriorly. The roof is almost flat in front of the parietal foramen, but from this foramen the surface ascends rapidly to the posterior margin. The margins of the orbits and nares are not elevated. The lateral arching is considerable posteriorly, including the quadratojugals, jugals, prosquamosals, and postorbitals. The underpart of the skull is in one plane, save in the region of the quadrates, the inner ends of which descend about 2^{cm} below the level of the rest.

The shape of the bones in the roof of the skull is well shown in Figs. 6 and 9. They resemble those of *Metoposaurus diagnosticus*, but present some notable differences. The premaxillæ are more elongate and narrower; the supraoccipitals are shorter; and the epiotics are proportionally narrower and shorter. The suture between the lachrymal and jugal has not been definitely determined, but the lachrymal reaches forward to the posterior border of the nares.[1] There is no prominent projection inward of the lachrymal between the orbits and nares. The quadratojugal articulates with the outer

[1] In the January number of the *Sitzungs-Berichte der Gesellschaft naturforschender Freunde*, Jaekel attempts to show that the prefrontal of the Reptilia is homologous with the lachrymal of the Mammalia, and he gives to the so-called lachrymal of the Reptilia the name "postnasal." The evidence that he presents does not, however, seem strong enough to warrant his conclusions.

upper corner of the quadrate, and takes no part in the articular surface as it does in *Mastodonsaurus*.

The orbits are in the anterior half of the skull and far apart, but they differ from those of *Metoposaurus* in being subcircular instead of oval. In a skull of *Metoposaurus diagnosticus* 405^{mm} long the orbits are 53^{mm} long by 32^{mm} broad.[1] In a skull of *Anaschisma* 415^{mm} long the orbits are 55^{mm} long by 49^{mm} broad. The external nares are ovate, with the apex near the tip of the snout, and they are larger and closer together than in *Metoposaurus*. In the skull of *Metoposaurus diagnosticus* mentioned above the nares are 35^{mm} long, 27^{mm} broad, and 48^{mm} apart; while in the skull of *Anaschisma* they are 49^{mm} long, 36^{mm} broad, and 35^{mm} apart. At the anterior end of the nares there are openings through the premaxillæ for the reception of the mandibular teeth. The parietal foramen is small, subcircular, and located about one-fourth the length of the parietals from the posterior end. No auditory slits are present, but the epiotics and prosquamosals have a slightly concave posterior margin in the region where the slits occur in other genera.

The bones of the roof are sculptured much as in *Metoposaurus*, but with much more of the space pitted, and without such long radiating ridges and furrows as in that genus. The pits are not so large, and the ridges between them are rounded instead of angular. None of the space in the lyra is furrowed.

The mucous canals of the lyra begin in a broad depression slightly inside of the posterior inner border of the orbits, and pass forward about 1½^{cm} inside the orbits, approaching a little nearer at their anterior inner corner. From the posterior inner angle of the prefontals the canals pass forward and outward in a straight line to about the middle of the outer margin of these bones, and thence forward in a straight line to the posterior outer corner of the nares. From here they pass inward and forward, following the margin of the nares. Near the tip of the snout the canals turn outward slightly, become shallower and broader, and end at the margin of the premaxillæ. They are nowhere very deep, and they maintain a width of a little more than 1^{cm} throughout their length.

The canals on the posterior part begin far back on the squamosals,

[1] *Paleontographica*, Vol. XXXVI, p. 142.

pass straight forward to in front of the middle of the postorbitals, thence outward and forward on the jugals, thence backward on the jugals and quadratojugals to near the base of the skull, where they turn upward slightly on the prosquamosal, and end at its posterior

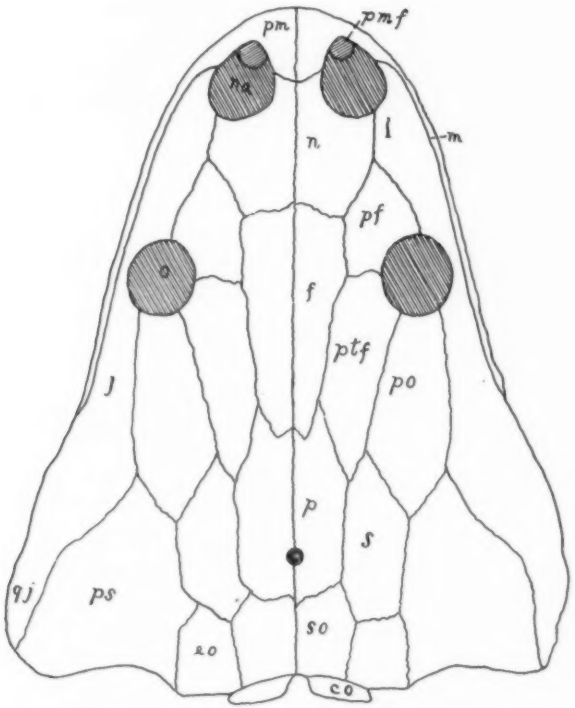

FIG. 1.—*Anaschisma browni;* view of top of skull, one-fifth natural size.
co, condyle; eo, epiotic; f, frontal; j, jugal; l, lachrymal; m, maxillary; n, nasal; na, nares; o, orbit; p, parietal; pf, prefrontal; pm, premaxillary; pmf, premaxillary foramen; po, postorbital; ps, prosquamosal; ptf, post-frontal; qj, quadratojugal; s, squamosal; so, supraoccipital.

margin. The part running forward on the squamosals and postorbitals is shallow and narrow, while the remainder is deeper and twice as broad.

The following are the dimensions of the skulls and of the openings in the roof:

	A	B
Skull—		
Total length	490mm	...
Length of roof	445	415mm
Breadth at posterior end	405	335
Breadth at posterior end of nares	190	158
Breadth at posterior end of orbits	270	235
Height at base	120	105
Orbits—		
Length	57	55
Breadth	46	49
Distance apart	122	110
Distance from posterior end of skull (median line)	240	220
Distance from anterior end of skull	180	170
Nares—		
Length	55	49
Breadth	42	36
Distance apart	32	35
Distance from anterior end of skull	40	36
Distance from orbits	86	90
Parietal foramen—		
Length	...	11
Breadth	...	9
Distance from posterior end of skull	...	57
Distance from orbits	...	155

Under side of skull.—The parasphenoid is long, slender, expanded posteriorly, and with a long, slender, cultriform process anteriorly. Its greatest length in A is 335mm, in B 310mm. The width along the shaft is about 40mm in A, 38mm in B. The prevomers articulate with it on each side along the anterior two-fifths of its length. Between the prevomers the width gradually decreases forward to about 15mm from its anterior end, where it is 8mm broad. From here to the anterior end its edges are parallel. Its greatest width, 75mm in A, 70mm in B, is at the posterior end of the palatine foramina. Posterior to this it is nearly semicircular as seen from below, but it sends out a wing-like process on either side that is overlapped by the pterygoid and exoccipital. At the posterior end on the upper side are two elongated oval pits, one on each side of the median line. They are about 10mm apart at their closest approach, and extend obliquely backward from the median line.

In general appearance the parasphenoid resembles that of *Metoposaurus*, but differs from it in the rounded posterior part and the slender cultriform process. The posterior part in *Metoposaurus diagnosticus*, as figured by Fraas,[1] resembles the posterior part in

[1] *Paleontographica*, Vol. XXXVI, Plate XIII.

Anaschisma as seen from above. The anterior part of the cultriform process resembles that of *Capitosaurus*.

The pterygoids form a considerable portion of the back part of the under side of the skull. A long anterior wing, about 32^{mm} wide posteriorly, but broadening abruptly to a width of 52^{mm}, 60^{mm} in advance of the posterior part of the palatine foramina, separates the palatine and infratemporal foramina, and articulates with the parasphenoid and exoccipitals. The posterior outer wing is narrow where it diverges from the main part of the bone, but broadens abruptly, sending up a broad triangular wing, which reaches the prosquamosal above, articulates with the quadrate at its outer end and forms a large part of the base of the skull. In the middle of the lower portion on the posterior side of this broad wing there is a deep, oval pit, with a groove running forward from it.

Passing upward from the pterygoid, just in front of the place where the posterior wing diverges, there is a slender, incompletely ossified bone that ends freely above. If the slender column continued upward, it would articulate with the parietals above. In *Gondwanosaurus*,[1] two slender bones articulate with the parietals above, and it is probable that these are the same elements that occur in *Anaschisma*, though more completely ossified in the former genus. This bone is probably the epipterygoid.

The palatines are long and slender. The posterior part reaches as far back as the hinder part of the orbit, and is wedged in between the maxillary and the transverse. A slender branch, with a minimum width of 1^{cm}, passes inward between the palatine foramen and the internal naris, and articulates with the prevomer. Between the naris and the maxilla the bone is narrow, but it broadens again in front of the naris. About 2^{cm} anterior to the naris there is a large tooth, and just in front of this the palatine articulates with the premaxilla. The palatine bears only the one tooth.

The prevomers are paired. Posteriorly they are separated by the cultriform process of the parasphenoid, but anteriorly they meet in a suture in the median line of the skull. A slender, tapering process runs backward from the posterior inner part of the bone

[1] *Palæontographica Indica*, Series IV, Vol. I, "The Bijori Labyrinthodont," p. 4, Plate I.

between the parasphenoid and the palatine foramen. From the postero-outer corner a short process projects between the nares and the palatine foramina to articulate with an inward projection of the palatine. In front of the internal nares the prevomers articulate with the palatines as far as the anterior edge of the large palatine

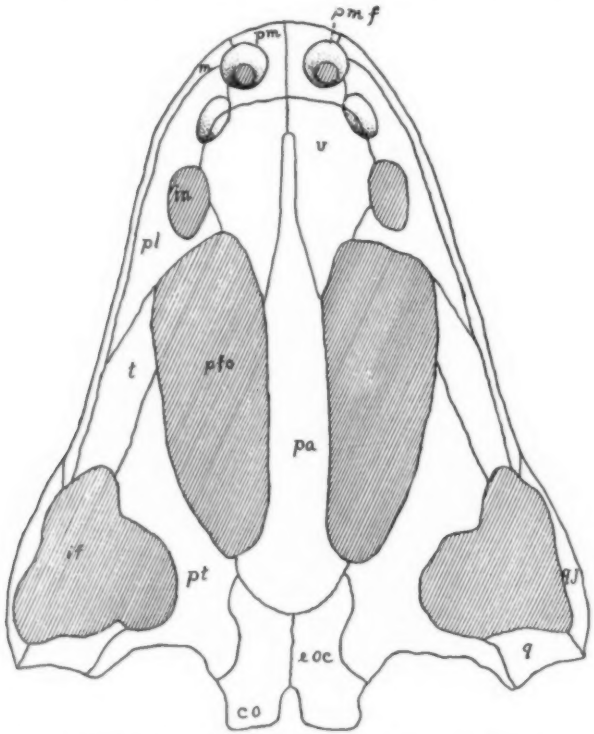

FIG. 2.—*Anaschisma browni;* palatal view of skull, one-fifth natural size.

co, condyle; eoc, exoccipital; if, infratemporal foramen; in, internal nares; m, maxillary; pa, parasphenoid; pfo, palatine foramen; pl, palatine; pm, premaxillary; pmf, premaxillary foramen; pt, pterygoid; q, quadrate; qj, quadrato-jugal; t, transverse; v, vomer.

tooth. From this point the anterior margin passes inward in a broadly rounded curve to the median line, which it meets about 5^{cm} posterior to the tip of the snout. There is a series of four or more small teeth on the anterior margin of each prevomer.

The transverse is a small bone, about 14^{cm} long by 3^{cm} broad, which articulates with the maxillary on the outside, with the pterygoid on the inside, and with the palatine in front. The suture between the transverse and the pterygoid has been definitely determined only on the right side of A, but it is indicated on the left side of the same skull and on the left side of B, where the bones are not so well preserved. The suture between it and the maxilla is distinct, but the one between it and the palatine is almost indistinguishable; only on the right side of A can it be distinguished with any degree of certainty, and even here a second line back of the one indicated in Plate II has very much the indication of a suture. On the right side of the same skull the bones are partially lost in the place where the palatine and transverse meet, but there is an indication of a suture in the same region as the one shown on the left side.

Viewed from the under side of the skull, the premaxillæ are nearly rectangular in shape. Each is pierced by a large opening for the passage of a mandibular tooth. This opening occupies more than half of the area of the bone. It is conical in shape, with the apex of the cone passing through the anterior end of the external nares. The suture between the premaxillæ and the maxillæ has not been definitely determined, but it appears to be just outside the opening for the mandibular tooth. The teeth are all broken off at the surface of the bone. Their sockets are no larger than those on the anterior part of the maxillæ. The suture between the premaxillæ and nasals is directly between the external nares.

The maxillæ are very slender. They extend from just outside the external nares to the anterior end of the infratemporal foramen. They bear a single series of small teeth that seem to increase gradually in size anteriorly. Only the roots of the teeth are preserved, and unfortunately most of them are badly obscured.

The palatine foramina are long, narrow posteriorly and expanded anteriorly. The infratemporal foramina are short and broad. The internal nares are large, oval, and situated near the anterior end of the palatine foramina. The premaxillary foramina are large and nearly circular.

The openings on the inferior side of the skull are almost perfectly shown in both specimens. The following table gives their dimensions:

	A	B
Premaxillary foramina—		
Length	24mm	22mm
Breadth	28	23
Distance apart	20	20
Distance from tip of skull	14	24
Internal nares—		
Length	50	46
Breadth	30	26
Distance apart	120	110
Distance from tip of skull	...	...
Palatine foramina—		
Length	225	200
Breadth	76	71
Distance from premaxillary foramina	100	105
Distance from internal nares	10	13
Distance from tip of skull	145	145
Distance from end of condyle	125	...
Infratemporal foramina—		
Length	130	115
Breadth	115	82
Distance apart	165	150

Base of skull.—The base of the skull is in an excellent state of preservation in A, but in B the upper part of the exoccipitals, the opisthotics, and the downward projections of the supraoccipitals are missing. The shape is well shown in Figs. 3 and 3*a*. The roof is regularly convex; the under border nearly plane, save for a downward projection at the union of the quadrate and pterygoid.

The foramen magnum is large, oval, and no projections inward from the exoccipitals tend to divide it into two parts as in *Mastodonsaurus* and *Metoposaurus*. The foramen more nearly resembles that of *Capitosaurus stantonensis* Woodward, though even in that form there is a slight projection inward from the sides, while in *Anaschisma* the sides are slightly concave outward. No fragments of cartilage or bone are present to indicate the presence of partially ossified basioccipitals or supraoccipitals, as in *Capitosaurus stantonensis* Woodward.[1] Between the exoccipitals and opisthotics below, and epiotics and supraoccipitals above, there is a small foramen, rounded above and angular below. This foramen is homologous with the posttemporal foramen of reptiles, as will be readily understood by reference to the text-figure of the base of the skull of *Eryops*, in which the relationship of the foramen is the same as in *Anaschisma*, though the opisthotic and foramen are larger.

[1] *Proceedings of the Zoölogical Society of London*, 1904, Vol. II, p. 172.

At the infra-basal angle of the skull there is an elongate oval foramen which clearly bears the same relation to its investing bones as does the quadrate foramen in the Ichthyosaurs, and nearly the same relation as in Sphenodon, the parasuchians some of the theropod dinosaurs, and *Dimetrodon*. On the outside it is bounded by the prosquamosal and quadratojugal; below and on the inside, by the quadrate. In Sphenodon, the parasuchians, theropod dinosaurs, and *Dimetrodon* the squamosal does not enter into the outer wall of the foramen. Dr. A. S. Woodward figures this foramen, and calls it the posttemporal.[1] The posttemporal in reptiles is bounded on the inside by the exoccipitals and supraoccipitals, below by the exoccipitals or opisthotics or both, on the outside by the squamosal or parietal or by both, and above by the parietal and squamosal. As the relations of this foramen in *Anaschisma* and *Capitosaurus* are entirely different from those of the posttemporal foramen in reptiles, it cannot be homologized with that foramen. On a previous page it is shown that another foramen is homologous with the posttemporal foramen of reptiles. As the relations of this opening are almost identical with those of the quadrate foramen in reptiles, it is here considered as homologous with that foramen.

Case postulates[2] that the quadrate foramen is in its inception in *Dimetrodon*, but its presence in the Labyrinthodontidæ indicates that it is a much more primitive character than he supposed.

The exoccipitals are expanded in the base of the skull, articulating with the parasphenoid in front, with the pterygoids on the outer sides, and with each other in the median line. The two condyles form strong projections from the posterior part. Passing upward and slightly forward from near the end of the condyles, there is a strong column which divides at the upper end, one branch meeting a downward projection of the supraoccipitals, the other articulating with the opisthotic. The lateral margins of the foramen magnum, formed by the inner part of the exoccipitals and the downward projections of the supraoccipitals, curve gently outward. Just above the condyle on the posterior inner side of the upward projection of

[1] *Loc. cit.*, p. 172.

[2] *Transactions of the American Philosophical Society*, 1905, Vol. XXI, Part I, p. 10.

the exoccipitals a small round foramen for the exit of the vagus and glossopharyngeal nerves appears. Quenstedt figures[1] this foramen in *Mastodonsaurus*, and Fraas figures[2] it in *Cyclotosaurus*, but in both these forms it is on the outer side of the bone.

The opisthotics are separate elements in *Anaschisma*, as in *Cyclotosaurus* and *Capitosaurus*. They are very short and slender. They

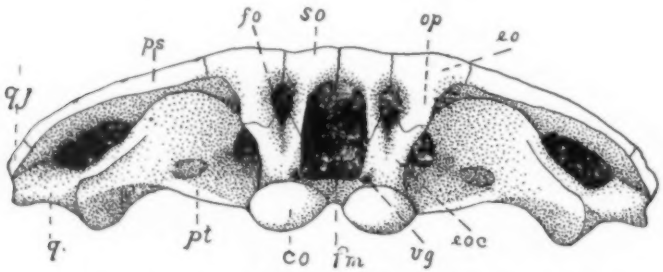

FIG. 3.—*Anaschisma browni;* hinder view of occiput, one-fourth natural size.
co, condyle; eo, epiotic; eoc, exoccipital; fm, foramen magnum; fo, posttemporal foramen; op, opisthotic; ps, prosquamosal; pt, pterygoid; q, quadrate; qj, quadratojugal; so, supraoccipital; vg, foramen for the vagus and glossopharyngeal nerves.

FIG. 3a.—*Anaschisma browni;* photograph of hinder view of occiput.

pass diagonally upward and outward from the exoccipitals to articulate with the epiotic at the outer end. The suture between them and the epiotic is not distinct.

Mandibles.—The left ramus of the mandible of A and the right ramus of B were procured with the skulls. A small part of the anterior end of A is missing, but B is almost complete, and the sutures

[1] *Die Mastodonsaurier im grünen Küpersandsteine Württemberg's sind Batrachier* (1850), Table II, Fig. 4.

[2] *Paleontographica*, Vol. XXXVI, Plate XI, Fig. 1, p. 132.

between the bones are readily made out. Because B is the more complete, the measurements given in the following description are taken from it.

The total length along the curve of the mandible is 495^{mm}. The greatest breadth, 94^{mm}, is a little in front of the cotylus, but a breadth of 90^{mm} or more is maintained for half the length of the ramus. Thirteen millimeters from the symphysis, the most anterior part where the full width is preserved, it is 65^{mm} broad. It is probable that at the symphysis the width was not greater than 50^{mm}. The greatest thickness is about 50^{mm}, just in front of the cotylus, where the upper part thickens abruptly. Just anterior to this the thickness decreases to 22^{mm}, and remains about the same to the symphysis. The post-cotyloid process is well developed.

The articular forms the greater part of the concave cotylus, and appears as a narrow ridge in the upper part of the postcotyloid process. It broadens abruptly as it enters the cotylus, and is of nearly uniform width to the anterior part, where it forms part of the posterior boundary of the supra-meckelian foramen. The greater portion of the inner side of the posterior part of the mandible is formed by the prearticular.[1] It projects from the end of the postcotyloid process to near the anterior end of the supra-meckelian foramen. Its upper edge forms most of the inner boundary of this foramen, and projects above the articular on the inner side. Its lower anterior part forms the boundary of the upper posterior corner of the mandibular foramen. Below it articulates with the angular for most of its length.

The angular extends the full length of the jaw on the outside, but articulates with an element anterior to it about 10^{cm} from the symphysis on the inside. On the inside it is narrow at the posterior end, broadens gradually to the mandibular foramen, where it narrows abruptly to form the part of the jaw between this foramen and the lower margin. In front of the foramen it broadens again abruptly. On the outside of the jaw the angular occupies about half the width anterior to the cotylus, but narrows rapidly behind it. It is coarsely pitted posteriorly, and ornamented with long radiating ridges and furrows anteriorly.

[1] Williston, *Field Columbian Museum Publication* 73, Geological Series, Vol. II, No. 1, p. 32; Kingsley, *American Naturalist*, Vol. XXIX, p. 61 (Dermarticulare).

The surangular is large. It articulates with the angular below in a line that runs diagonally from the postero-inferior angle of the jaw to a point just below the anterior end of the coronoid. Above it articulates with the dentary and articular, and forms part of the outer boundary of the supra-meckelian foramen. It is coarsely pitted posteriorly with coarse ridges running upward and forward from the pitting.

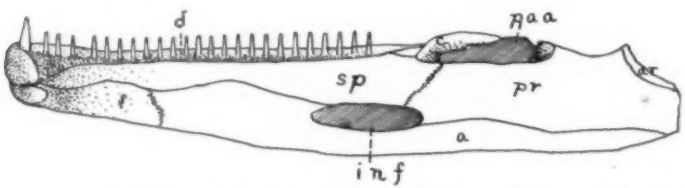

FIG. 4.—*Anaschisma brachygnatha;* right ramus of mandible, one-fifth natural size.

a, angular; c, coronoid; d, dentary; inf, internal mandibular foramen; paa, supra-meckelian foramen; sp, splenial; ?, probably a separate element; pr, prearticular

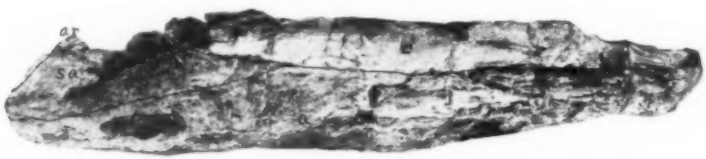

FIG. 4*a*.—*Anaschisma browni;* outer view of right ramus of mandible, one-third natural size.

a, angular; ar, articular; d, dentary; sa, surangular.

The dentary forms the upper half of the jaw in front of the middle of the supra-meckelian foramen. It is not sculptured. The teeth are set on the top of the inner side, and on the outer side there is a high, thin parapet which forms the outer margin of the jaw, and in which the outer sides of the teeth are imbedded for the height of 1^{cm} or more.

The coronoid is a small element at the anterior end of the supra-meckelian foramen. The main part of it forms the front margin of this foramen. The anterior part is slender and triangular, and is wedged in between the splenial and dentary.

The splenial extends from the prearticular to near the symphysis,

but takes no part in the symphysis. It occupies the upper half of the inside of the mandible, and is very thin.

Below the splenial, and in front of the angular, an element that seems to be separate from the dentary is present. The suture between it and the dentary is not distinct, but at the symphysis the dentary seems to be separate from it. This seems to be a separate element in *Eryops* also, but the evidence is not conclusive in either case.

On the upper border of the mandible, just in front of the cotylus, there is an opening for Meckel's cartilage. For convenience in description, this is called the supra-meckelian foramen. Perhaps a name has been given to it previously, but, if so, the writer has failed to find it. It is subtriangular in shape, 85^{mm} long by about 40^{mm} in greatest width. On the inner side the articular projects farther forward than on the outer, making the posterior margin of the foramen diagonal to the long axis of the jaw. The apex of the foramen lies between the splenial and coronoid, while the inner and outer sides are formed by the prearticular and surangular.

The jaw is hollow throughout, the bones forming a mere shell, usually only a few millimeters in thickness. The cavity extends from the symphysis to the tip of the postcotyloid process with its greatest size in the region of the prearticular foramen.

The vertebræ.—As before stated, there are about forty vertebræ referred to *Anaschisma* in the collection, but none of them has the arch preserved. Among them are two imperfect atlases of an oval shape, about 70^{mm} broad by 50^{mm} high. Anteriorly they have two slightly concave faces for articulation with the condyles; posteriorly they are concave. A supposed axis is oval, and about the same size as the atlas. It is opisthocoelous. On each side at about the middle of the vertebræ there is a large, shallow facette for the articulation of a rib. The thoracic vertebræ are nearly circular in shape, varying from 40 to 65^{mm} in diameter. One of these shows that the ribs were borne on exogenous processes arising from both the arch and body. The caudals are smaller, proportionally longer, with the vertical diameter greater than the transverse. All of the vertebral articular surfaces are for the articulation of single-headed ribs.

Among the vertebræ present there are three others besides the axis that are opisthocoelous. Whether they belong to a different

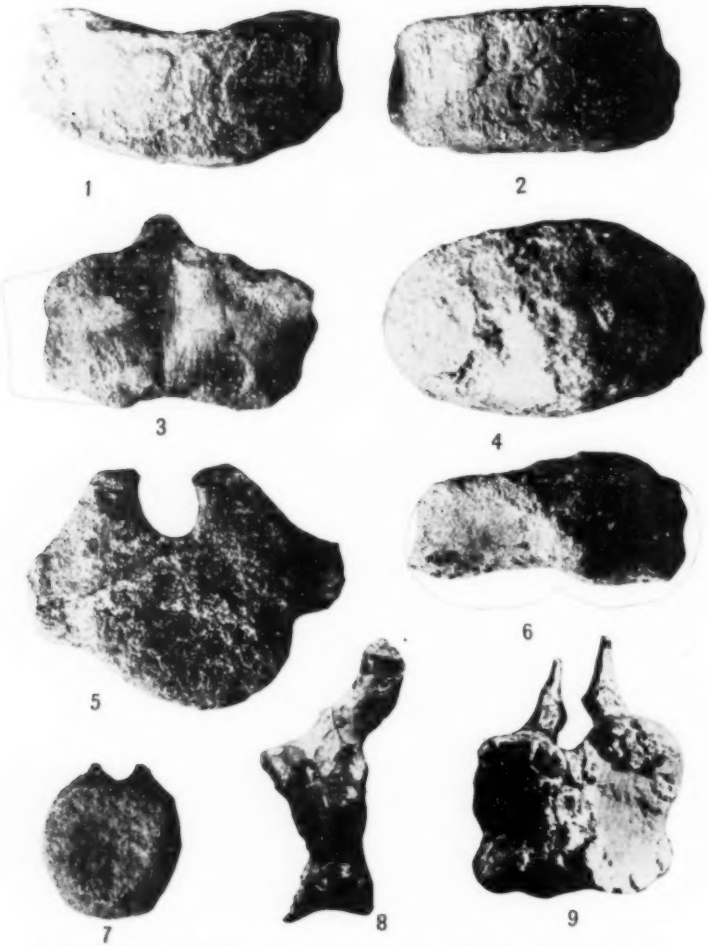

FIG. 5.—Vertebræ of *Anaschisma* and *Eryops*, two-thirds natural size.

1. Dorsal view of axis of *Anaschisma*.
2. Upper view of a dorsal vertebra of *Anaschisma*.
3. Upper view of atlas of *Anaschisma*,.
4. View of anterior end of axis of *Anaschisma*.
5. View of anterior end of a dorsal vertebra of *Anaschisma*.
6. View of anterior end of atlas of *Anaschisma*.
7. Caudal of *Anaschisma*.
8. Lateral view of atlas of *Eryops*.
9. View of anterior end of atlas of *Eryops*.

type of animal or to a particular region in the column of *Anaschisma* it is impossible to say. They agree in all respects with the others, save in being opisthocoelous. All of the others are slightly amphicoelous.

Pectoral girdle.—The clavicles and interclavicles collected from the Lander region were in such a poor state of preservation that nothing has been made out concerning their characters to add to what Mr. Lucas has published about *Metoposaurus fraasi.* One of the interclavicles evidently belongs to that species, but some of the others show very different types of sculpturing, and probably belong to different genera.

A cleithrum was found in position with one of the clavicles. It was complete when the writer removed it from the rock, but unfortunately part of the upper end was lost in transportation. In the figure this is restored. The bone is about 12^{cm} long, expanded at the base, and tapering to a point at the top. It projects upward and forward from the antero-outer end of the clavicle at an angle of about 45°. It is very different in shape from the cleithra that have been described from other Stegocephalians, but it can be homologized with no other element.

FIG. 6.—*Anaschisma;* cleithrum, natural size.

Anaschisma browni, *sp. nov.*

(Figs. 7, 8, and 10)

Skull broad posteriorly; proportion of greatest length to greatest width about 10 to 9. Bones of roof of skull coarsely sculptured, pitting predominating anteriorly, ridges and furrows posteriorly. Mucous canals of the lyra beginning in a deep depression just inside

the postero-inner corner of the orbit. The main part of the posterior mucous canals begins on the postfrontals, and passes backward in a broad curve to a point in front of the middle of the postorbitals,

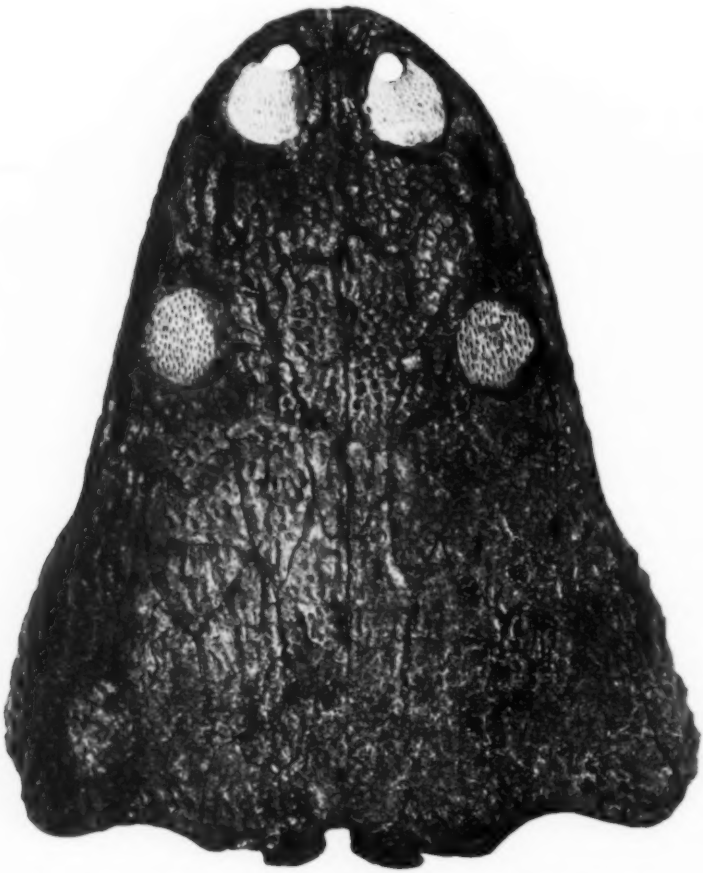

FIG. 7.—Upper view of skull of *Anaschisma browni*, one-third natural size.

where the part passing forward on the postorbitals meets it. It then turns at a sharp angle and passes outward and forward. Eyes large, subcircular, situated in anterior half of skull; nares large, approxi-

mated; infratemporal foramina very broad; internal nares close to the palatine foramina. Maxillary and premaxillary teeth small; a few small teeth on the vomers in a row parallel to those on the pre-

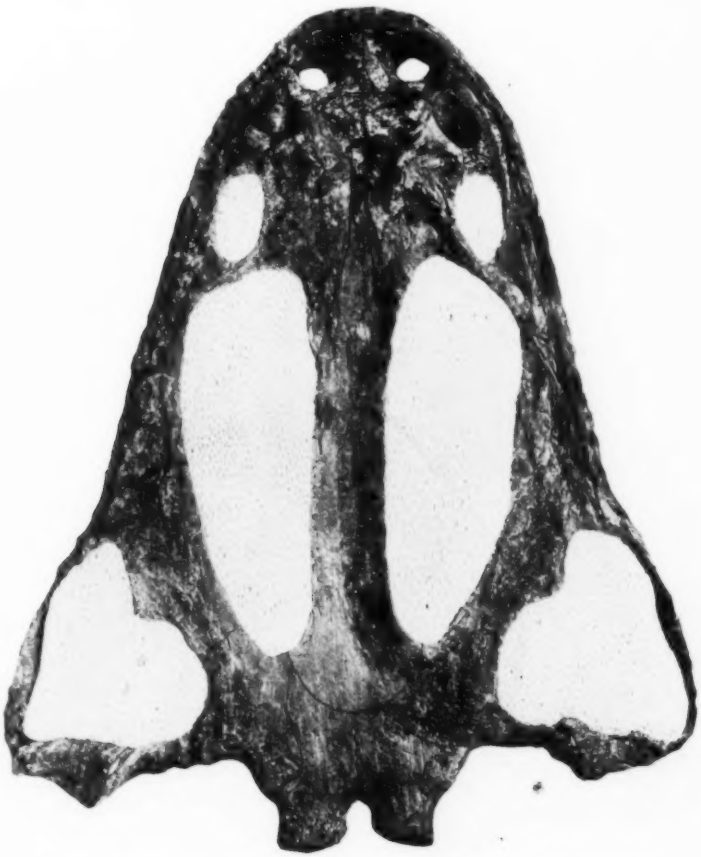

FIG. 8.—Palatal view of skull of *Anaschisma browni*, one-third natural size.

maxillæ; mandibular teeth compressed, with the long axis transverse to the long axis of the jaw; a very large tooth on each palatine a little in front of the internal nares; a few teeth on the transverse.

Anaschisma brachygnatha, ***sp. nov.***

(Figs. 9 and 10)

This species differs from *Anaschisma browni* as follows: Skull much narrower posteriorly in proportion to the length; proportion

FIG. 9.—Upper view of skull of *Anaschisma brachygnatha;* one-third natural size.

of length to breadth about 5 to 4. Eyes not as far forward; nares farther apart. Bones in roof of skull with finer pitting, and broader, more rounded ridges between the pits. Mucous canals of the lyra

beginning farther back, and in a broader, shallower depression. The posterior canals beginning in a broad, shallow depression on the postorbitals, instead of on the postfrontals. Infratemporal foramina much narrower; internal nares much farther from the palatine foramina. Teeth as in *A. browni*.

1. Inner view of mandible of *Anaschisma brachygnatha;* one-fourth natural size.
a, angular; ar, articular; c, coronoid; d, dentary; ?, undetermined; pa, preartcular; s, splenial.

2. Lateral view of skull of *Anaschisma browni;* two-ninths natural size.
c, condyle; if, infratemporal foramen; n, internal nares; pf, palatine foramina; q, right quadrate; q^1, lower end of left quadrate.

FIG. 10

DESCRIPTIONS OF ALL OTHER LABYRINTHODONTIDÆ KNOWN FROM AMERICA

Metoposaurus fraasi Lucas

Original description:[1]

The species is characterized by the coarseness of the sculpturing of the episternum, and the fact that the markings of the center of the plate consist of irregular pits which, toward the margin, are transformed into radiating grooves. These grooves are most marked on the anterior portion of the bone. The portion of clavicles present also have the ornamentation in the shape of pits rather than grooves, and in this respect and in the greater coarseness of the sculpture the present species differs from the European *Metoposaurus diagnosticus* of von Meyer. It is, furthermore, characterized by the extent of the articulation of the clavicle with the episternum, the posterior end of the clavicle being well behind a line drawn through the center of the plate. The postero-inner angle of the

[1] *Proceedings of the United States National Museum*, 1904, Vol. XXVII, p. 194.

clavicle is very much rounded, instead of being decidedly angular, as it is in *Metoposaurus diagnosticus*.

The episternum is 43^{cm} long and 30^{cm} wide.

The mandible is coarsely sculptured on the external face, and bears indications of two large teeth at the very front of the ramus, and behind these fifteen small teeth. These seem to have been largely attached to the external wall of the alveolus in a manner somewhat suggestive of the pleurodont dentition of an iguana.

Specimen from Trias five miles east of Tanners Crossing, Little Colorado River, Arizona.

This specimen is probably an *Anaschisma*, but only the finding of such interclavicles with a skull of *Anaschisma* will settle that point definitely.

Dictyocephalus Leidy

(No name) Emmons, 1856 (*Geological Report of the Midland Counties of North Carolina*, p. 347).

Dictyocephalus Leidy, 1856 ("Notice of Extinct Vertebrated Animals Discovered by Professor E. Emmons," *Proceedings of the Academy of Natural Sciences of Philadelphia*, p. 256; also *American Journal of Science*, 1857, Vol. XXIII, p. 272).

Dictyocephalus Emmons, 1857 (*American Geology*, Part VI, p. 59, Figs. 31 and 32).

Dictyocephalus Emmons, 1860 (*Manual of Geology*, 2d ed., p. 184, Fig. 182).

Dictyocephalus Cope, 1868 ("Synopsis of Extinct Batrachia of North America," *Proceedings of the Academy of Natural Sciences of Philadelphia*, p. 221).

Dictyocephalus Miall, 1875 ("On the Structure and Classification of the Labyrinthodonts," *Report of the British Association for the Advancement of Science*, p. 185).

Dictyocephalus Cope, 1875 ("Synopsis of the Vertebrata Whose Remains Have Been Preserved in the Formations of North Carolina," *Report of the Geological Survey of North Carolina*, Appendix, B p. 32).

Dictyocephalus Fritsch, 1879 (*Fauna der Gaskohle und der Kalksteine der Permformation Böhmens*, Vol. I, p. 61).

Dictyocephalus Zittel, 1890 (*Handbuch der Palaeontologie*, Vol. III, p. 408).

Dictyocephalus von Huene (*Uebersicht über der Reptilien der Trias*, p. 68).

Founded on the upper portion of a cranium discovered by Professor Emmons in the coal fields of Chatham County, North Carolina. Plates of the cranium covered with reticular ridges in a general radiant manner. Parietals comparatively short, broader in front than behind; parietal foramen near the center of the bones. Occipi-

tals quadrate, a little longer than broad. Posterior outline of the cranium with a superficial transverse concavity on each side, and not with a deep sinus as in *Trematosaurus* and *Archegosaurus*. Breadth of occipital outline 28 lines; length of parietals 8½ lines; breadth anteriorly 3¾ lines, posteriorly 3 lines. Probable length of head, considering it to have nearly the proportions of *Trematosaurus*, 4 inches, breadth 2½ inches.[1]

Eupelor Cope

Mastodonsaurus Cope, 1866 ("Observations on Extinct Vertebrates of the Mesozoic Red Sandstone," *Proceedings of the Academy of Natural Sciences of Philadelphia*, p. 250).

Eupelor Cope, 1868 ("Synopsis of the Extinct Batrachia of North America," *ibid.*, p. 221).

Eupelor Cope, 1869 ("The Extinct Batrachia, Reptilia, and Aves of North America," *Transactions of the American Philosophical Society*, Vol. XIV, p. 25).

Eupelor Miall, 1874 ("On the Structure and Classification of the Labyrinthodonts," *Report of the British Association for the Advancement of Science*, p. 186).

Eupelor Fritsch, 1879 (*Fauna der Gaskohle und der Kalksteine der Permformation Böhmens*, Vol. I, p. 62).

Eupelor Cope, 1886 ("Note on the Fossils of the Mesozoic Rocks in York County, Pa,." *Proceedings of the American Philosophical Society*, p. 403).

Eupelor Cope, 1887 ("A Contribution to the History of the Vertebrata of the Trias of North America," *ibid.*, p. 209).

Eupelor Zittel, 1890 (*Handbuch der Palaeontologie*, Vol. III, p. 408).

Eupelor Cope, 1892 ("A Preliminary Report of the Llano Estacado," Geological Survey of Texas, *Fourth Annual Report*, pp. 12 and 17).

Eupelor von Huene, 1902 (*Uebersicht über der Reptilien der Trias*, pp. 68–82).

Postorbitals 11^{cm} long; parietals 7^{cm} wide behind and 10^{cm} between the postorbitals. On the posterior part of the interorbital region commence two smooth, shallow sulci 29^{mm} apart; between them the surface is pitted four or five to the inch. The parietal bones are longitudinally sulcate throughout. All other bones with a coarse honeycomb pattern of sculpture, the pits becoming confluent into radiating grooves near the margins. Base of mandibular teeth cylindric, with shallow grooves. An interclavicle measures 345^{mm} long by 140^{mm} broad.

[1] *Proceedings of the Academy of Natural Sciences of Philadelphia*, Vol. VIII, p. 256.

The specimens that have been referred to this genus are the back part of a skull from Chester County, Pennsylvania, one ramus of a mandible, some teeth, an interclavicle, and some other fragments from York County, Pennsylvania, and some fragments from the Docum Beds of northwestern Texas. It is not at all certain that the specimens from York and Chester Counties belong to the same genus, and it seems very probable that the Texas specimens are generically distinct from those of Pennsylvania.

The data seem too meager to warrant a discussion of the relationship of this genus, but a few general conclusions may not be inappropriate. From the length of the postorbital it is evident that the part of the skull behind the orbits was shorter than in *Anaschisma*, but longer than in *Mastodonsaurus*. The breadth of the parietals posteriorly is about the same as in *Anaschisma*, but anteriorly they are much broader than in that genus. Since the mucous canals are only 3^{cm} apart between the orbits, it is probable that the orbits were approximated, though not so much so as in *Mastodonsaurus*. The interclavicle is proportionally narrower than in *Metoposaurus*. So far, then, as the characters that are known indicate, *Eupelor* is intermediate between *Mastodonsaurus* and *Anaschisma*.

In 1868 Cope referred[1] some teeth from Chester County, Pennsylvania, to this genus, but a year later he concluded[2] that they belonged to thecodont reptiles. Later he described teeth that he found *in situ*, in a mandible,[3] and suggested that those which he originally described were rightly determined. This is hardly probable, since these teeth are rarely found fossilized, except as stumps in the jaws, and his so-called thecodont reptiles teeth are not at all rare.

The known remains are all referred to one species, *Eupelor durus* Cope. No figures of the specimens have ever been published.

Pariostegus Cope

Pariostegus Cope, 1868 ("Synopsis of the Extinct Batrachia of North America," *Proceedings of the Academy of Natural Sciences of Philadelphia*, p. 221).

Pariostegus Cope, 1869 ("The Extinct Batrachia, Reptilia, and Aves of North America," *Transactions of the American Philosophical Society*, Vol. XIV, p. 10).

[1] *Loc. cit.*, p. 221. [2] *Loc. cit.*, p. 25.

[3] *Proceedings of the American Philosophical Society*, 1887, p. 209.

Pariostegus Cope, 1875 ("Synopsis of the Vertebrata Whose Remains Have Been Preserved in the Formations of North Carolina," *Report of the Geological Survey of North Carolina*, Appendix, p. 32).

Pariostegus Miall, 1875 ("On the Structure and Classification of the Labyrinthodonts," *Report of the British Association for the Advancement of Science*, 1874, p. 189).

Pariostegus Fritsch, 1879 (*Fauna der Gaskohle und der Kalksteine der Permformation Böhmens*, Vol. I, p. 64).

Pariostegus Zittel, 1890 (*Handbuch der Palaeontologie*, Vol. III, p. 488).

Pariostegus von Huene, 1902 (*Uebersicht über die Reptilien der Trias*, p. 68).

This genus is represented by a large part of the cranium of a batrachian from the Triassic coal-measures of Chatham County, North Carolina.

Contrary to what has been found the case in most genera of Stegocephalia, the maxillary appears to extend posteriorly to a free termination, as in modern Salamanders, and the supratemporal bone presents a very prominent, obtuse, arched margin. This margin extends from the margin on each side, and is inclined toward the posterior part of the cranium. There is therefore no quadratojugal piece.

The maxillary and mandibular pieces are slender, flat bones, as in *Menopoma;* the form of the posterior or articular portion of the latter cannot be ascertained from the specimen. The more or less exposed part of the median region of the latter exhibits a succession of shallow transverse notches, inclosing thirteen obtuse elevations. The former resemble rudimental lateral alveoli for minute pleurodont teeth. A few other similar minute ribs, and, perhaps, a minute curved cone without sculpture, are the only other indications of dentition.

A pair of narrow nasals, acuminate behind, penetrate between the frontals as far posteriorly as the posterior margin of the orbits. The suture between these is very distinct, and entirely straight. The preorbitals extend to above the orbit, and then appear to cease with a transverse suture. Between these and the nasals a broad triangular element enters on each side, not attaining the probable position of the nostrils. Each is divided by a longitudinal groove, which is probably a suture, and which would then divide the frontals from the parietals. The frontal would then divide the parietals entirely from the anterior

half of their length. This would give the frontals a narrow form, acuminate in front, and bounded behind by a regular, coarse, zigzag transverse suture. The cranium behind this point is rugose, and the surface not well preserved, and it can only be said that two peculiar grooves converge to a point between the posterior extremities of the frontals, like the boundaries of the supraoccipitals. When the postorbital roof bone is raised up, the meeting of the two gular dermal bones, as I interpret them, is seen. One of these is a plate directed backward and outward, bearing minute radiating lines on its upper surface. It meets a similar flat plate directed forward and outward, with similar lines radiating to the circumference.

The orbits are remarkably small, and situated probably near the middle of the longitudinal measurement of the cranium. The external nares are not defined, but symmetrical depressions in the position they usually occupy in Salamanders are distinct.

Pariostegus myops Cope

The surface of the cranial bones is little sculptured; there are small tuberculiform elevations on the parietal, and more numerous ones on the preorbitals. The postorbitals show the strongest markings of elongated pits, which radiate to their circumference, leaving a smooth, obtuse border. The nasals present a series of small warts at a little distance on each side of their common suture and transverse to it. The surface of the maxillary is marked with longitudinal grooves and shallow pits.

No suture separating maxillaries and premaxillaries can be traced with certainty, though the bones of the jaw are interrupted at the usual place of suture, opposite the nostril.

Length of specimen (including mandible)	18.0 lines
Width between outer convexities postorbitals	17.0
Width between inner borders orbits	11.0
Width of same without preorbitals	8.0
Width of nasals at middle	2.5
Width of orbit	1.5
Length of frontal and nasal premaxillary	11.0
Length of supposed branchihyal	12.0[1]

[1] *Proceedings of the Academy of Natural Sciences of Philadelphia*, 1868, p. 211.

Von Huene refers *Eupelor*, *Pariostegus*, and *Dictyocephalus* to the Temnospondyli, but their relationships, so far as can be made out from the fragmentary material known, are with the Stereospondyli.

In 1897 Dr. Williston described[1] a large labyrinthodont tooth from the upper part of the coal-measures near Louisville, Kansas. This tooth is as large and complex in structure as the large fangs of *Anaschisma*. The animal to which it belonged was probably one of the true Labyrinthodontidæ. The species was provisionally referred to *Mastodonsaurus*.

SOME NEW FACTS ABOUT ERYOPS

In the collection of vertebrate fossils of Walker Museum there is a specimen of *Eryops* of great interest from the Permian of Texas. It consists of an almost complete skull, a large number of vertebræ in association, the pectoral and pelvic girdles, and some limb bones. Most of the sutures in the roof of the skull are distinct; the under part and base of the skull are in a splendid state of preservation, and the characters of the sacral and presacral vertebræ are well displayed.

The writer has studied Cope's types of *Eryops*, and the present specimen is congeneric with them. It differs widely in three important characters from *Eryops* as restored by Broili:[2] the pterygoids do not meet in the median line; the prevomers are very large; the palatine foramina are small. Cope's types show these characters definitely, and the pterygoid region of twelve other skulls studied during the present investigation show that the pterygoids do not meet in the median line.

Skull.—The skull has been distorted by pressure, the right side being flattened, while the left side is pushed to the left at the top, and the lower margin crushed inward. A small part of the quadratojugal on each side, a part of the premaxillæ from the region of the maxillary foramen, some of the jugal, prosquamosal, postfrontal, and prefrontal of the left side, and a little of the squamosal and postorbital of the right side are missing.

[1] *Kansas University Quarterly*, Vol. VI, No. 4 (1897), p. 209.

[2] *Paleontographica*, Vol. XLVI, Plate VIII, Fig. 1.

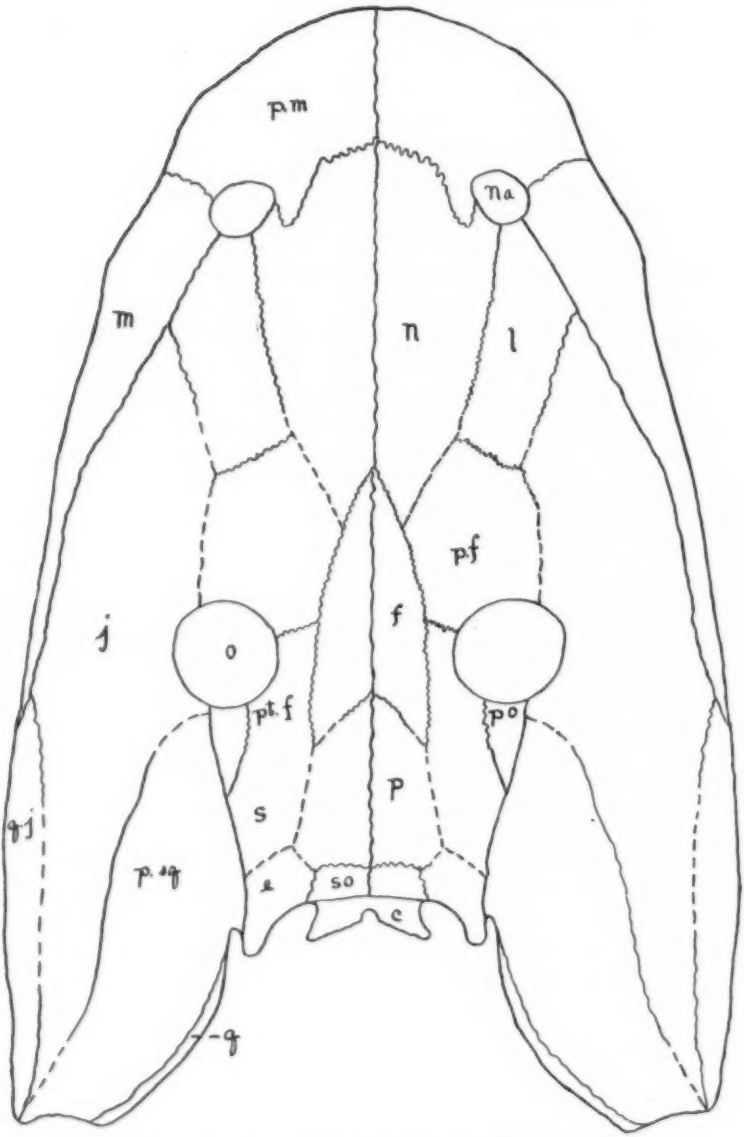

FIG. 11.—*Eryops* Cope; view of top of skull, four-thirteenths natural size.

c, condyle; e, epiotic; f, frontal; j, jugal; l, lachrymal; m, maxillary; n, nasal; na, nares; o, orbit; p, parietal; pf, prefrontal; pm, premaxillary; po, postorbital; ptf, postfrontal; qj, quadratojugal; s, squamosal; so, supraoccipital. Broken lines indicate that sutures have not been made out.

FIG. 110.—Palatal view of skull.

The bones in the roof of the skull resemble those in *Actinodon* and *Mastodonsaurus*. The parietals, frontals, postfrontals, and supraoccipitals are small. The prosquamosal is elongate, reaching from just behind the orbit to the outer end of the quadrate. The quadratojugal is long and narrow. The jugals are the largest bones in the roof of the skull; they extend from a short distance behind the nares to just in front of the outer end of the quadrate. The maxillæ are long, narrow behind, expanded anteriorly. The prefrontal is pentagonal in outline. It unites with the postfrontal behind, excluding the frontal from the border of the orbits. The lachrymals are elongate, pentagonal, and reach to the nares in front. The premaxillæ are greatly expanded. The nasals are elongate and subtriangular.

The orbits are about the same size and in about the same position as in the type of *Eryops*, though they are slightly farther apart. The nares are ovate, situated at a considerable distance from the tip of the skull, and are slightly larger than in Broili's specimens, though smaller than in most other large Stegocephalians. The auditory slits are very short and narrow. No parietal foramen is present.

The anterior part of the roof is very finely sculptured with irregular elongate and subcircular pits, the ridges between the pits becoming tubercular near the median line of the skull. Toward the occiput the sculpture becomes coarser, and on the outer part of the prosquamosal the pits elongate to form radiating furrows.

From the posterior part of the epiotic a prominent ridge passes forward and outward to the back part of the orbit. A less prominent ridge passes forward from the antero-inner corner of the orbit, and gradually disappears about midway between the nares and orbits. Just in front of the antero-outer corner of the orbits there is a large, shallow depression, with a narrow furrow extending forward from it for a short distance. About 5^{cm} behind the nares there is another depression, but it is not so large as the one anterior to the orbits. Running straight forward from it on the nasals there is an indistinct narrow sulcus; passing outward from the posterior outer corner there is a broader, less well-defined, sulcus which meets the sulcus from the preorbital depression. Whether or not these canals are homologous with the slime canals of other forms it is impossible to say, but it seems probable that they are rudiments of such canals.

The dimensions of the skull and of the openings in the roof and floor are as follows:

Length along margin of jaw	580^{mm}
Length along median line from tip of snout to posterior end of quadrates	540
Length from supraoccipital to tip of snout	445
Greatest breadth	350
Breadth at posterior end of orbits	325
Breadth at posterior end of nares	233
Distance from back part of nares to fore part of orbit	185
Distance of orbit from supratemporal	120
Distance apart of nares	100
Distance apart of orbits	90
Length of nares	31
Breadth of nares	29
Length of orbits	53
Breadth of orbits	56
Length of palatine foramen	180
Breadth of palatine foramen	90
Distance from tip of skull	200
Distance from end of condyle	65
Distance from internal nares	65
Length of internal nares	45
Breadth of internal nares	27
Distance from tip of snout	110
Length of infratemporal foramen	175
Breadth of infratemporal foramen	80

Under side of skull.—The under side of the skull is not in one plane, but is arched upward very strongly along the median line posteriorly. This arching is caused by the inner wings of the pterygoids turning abruptly upward.

The parasphenoid is comparatively much shorter than in Broili's specimens. One of the skulls which he describes is about 38^{cm} long, and has a parasphenoid 26^{cm} in length, while the skull described in this paper is 45^{cm} long and has a parasphenoid only 22^{cm} in length. The parasphenoid is expanded in the middle and in front of the expansion tapers gradually to a point between the prevomers. Behind the expanded part it tapers gradually to near the posterior end, where it broadens slightly, separating the pterygoids and articulating with the exoccipitals. The parasphenoid does not separate the pterygoids

or articulate with the exoccipitals in Broili's specimens. It has a broader median expansion than in this form, is narrower behind, and contracts more abruptly in front of this expansion, and has a much longer, slenderer cultriform process.

The prevomers are broad and thin. They articulate anteriorly with the premaxillæ in a straight line that runs at right angles to the main axis of the skull. On the outside they articulate with the pterygoids and palatines. They articulate with each other in the median line of the skull for the anterior half of their length, then pass backward on either side of the parasphenoid, and end just in front of the median expansion of that bone. They form the anterior inner boundary of the palatine foramina.

The palatines are long and slender, and extend from the middle of the outer margin of the skull to the anterior end of the internal nares. They are broadest immediately behind the nares, narrowest just inside their posterior end, and they form their entire inner and posterior borders. They bear three large teeth, one at the back end, one just behind the nares, and one immediately inside the anterior end of the nares.

The pterygoids have very long anterior and posterior wings, and a short, thick inner wing. The anterior wing is broad at the outer end between the maxillary and the palatine foramen, but becomes narrower anteriorly between this foramen and the palatine bones. It is narrower between the infratemporal and palatine foramina, and the part that forms the inner boundary of the former is turned upward at right angles to the main part of the bone. Just inside this upturned portion there is a deep depression that extends forward, becoming broader and shallower, until it finally disappears. The posterior wing is twisted on the main part of the bone until only the edge is seen from below. It articulates with the quadrate at the outer end and above, and projects outward nearly to the cotylus. The inner wings are present in six specimens preserved in Walker Museum, and in every specimen they are broadly separated by the parasphenoid, instead of meeting in the median line as in Broili's specimens.

The premaxillaries are greatly expanded, forming the anterior fifth of the floor of the skull.

The palatine foramina are much shorter than those shown in Broili's restoration of *Eryops*. They are separated by the parasphenoid and prevomers. The infratemporal foramina are long and narrow. The internal nares are large, rounded posteriorly and pointed anteriorly, and are widely sseparated from the palatine foramina. As the premaxillaries are somewhat imperfect anteriorily, the shape of the premaxillary foramina cannot be definitely determined. They do not penetrate the roof of the skull.

Base of skull.—The foramen magnum is remarkable because of its small size. In none of the specimens in the collection does its greatest diameter exceed 2^{cm}. As it is distorted by pressure, in all of the skulls, it is impossible to determine its exact shape, but it seems to have been oval, with its transverse diameter the greater.

The exoccipitals form the margins of the foramen, except above, where the supraoccipitals project downward between them. In the floor of the skull the exoccipitals are thick, and co-ossified with each other and with the parasphenoid. The condylar processes are short and strong, and the articular surfaces are concave. A short, strong upward projection from just in front of the condyles forms the lateral boundary of the foramen magnum and broadens to a head above, articulating firmly with the supraoccipitals. A long, slender lateral process, homologous with the opisthotic (paroccipital, Baur) of reptiles, passes outward to articulate with the epiotic (paroccipital plate, Baur) at its outer end. Between this process and the bones of the roof of the skull there is an elongate oval foramen, which is homologous with the posttemporal foramen of the Reptilia.

The posterior wing of the pterygoid, where it turns upward to articulate with the quadrate, forms a considerable part of the base of the skull. The quadrate extends from the cotylus to the auditory slit, showing as a long, narrow strip in the base of the skull. Along its entire upper edge it articulates firmly with the prosquamosal, along its lower edge with the pterygoid. The quadratojugal meets it at its lower outer corner. The surface for articulation with the mandible is somewhat saddle-shaped, and is formed entirely by the quadrate.

Mandible.—The sutures in the mandible of *Eryops* have never before been determined, but in all of the specimens in Walker Museum

most of them are distinct. In Figs. 13 and 13*a* the sutures are indicated. The suture between the prearticular and the splenial has not been definitely located.

The articular is short and thick. It is covered on the outside by the angular and surangular, and on the inside by the angular and prearticular. The articular surface is convex, the convexity passing diagonally forward from the posterior inner corner. The coronoid is very small, and is situated in front of the supra-meckelian foramen, as in *Anaschisma*. The dentary is slender, sculptured anteriorly,

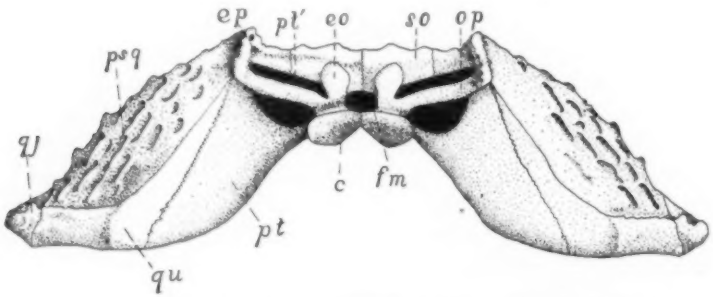

FIG. 12.—*Eryops* Cope; hinder view of occiput, one-third natural size.

c, condyle; eo, exoccipital; ep, epiotic; fm, foramen magnum; op, opisthotic; pt', posttemporal foramen; pt, pterygoid; psq, prosquamosal; qj, quadratojugal; qu, quadrate.

and smooth posteriorly. The posterior end of it projects a little way behind the coronoid. There is a high, thin parapet on the upper side of the outer part of the bone, and the outer edges of the teeth are imbedded in it. The angular forms the greater part of the outside of the mandible in front of the supra-meckelian foramen. The suture between the angular and surangular has not been definitely determined. The splenial is slender and very thin. It projects above the inner edge of the dentary anteriorly, but gradually descends posteriorly. The portion in front of the angular (Fig. 13, ?) seems to be an element separate from the dentary. The suture between it and the dentary appears to be near the lower edge of the jaw on the outer side. As previously stated, this element seems to be distinct in *Anaschisma*, but the evidence in neither case is conclusive.

The internal mandibular foramen is small, oval, situated between

the angular and prearticular directly below the anterior end of the supra-meckelian foramen. The supra-meckelian foramen is elongate and narrow.

The sculpture on the outside of the mandible consists of longitudinal ridges and furrows above, but these become coarser and have more of the pitted character below.

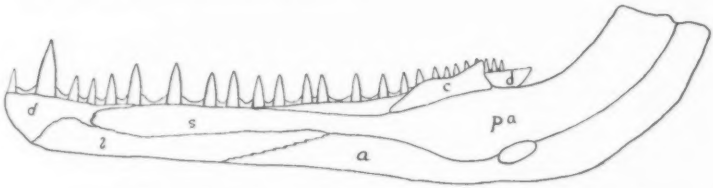

FIG. 13.—*Eryops* Cope; inner view of mandible, one-fourth natural size.
a, angular; d, dentary; c, coronoid; pa, prearticular; s, splenial; ?, probably a separate element.

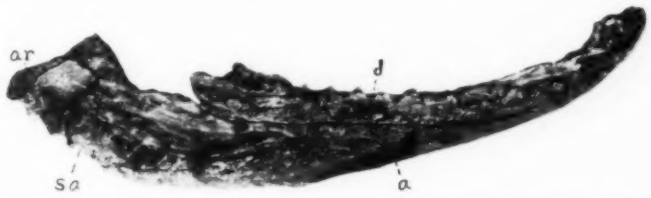

FIG. 13*a*.—*Eryops* Cope; outer view of mandible, one-third natural size.
a, angular; ar, articular; d, dentary; sa, surangular.

Vertebræ.—Belonging with the skull above described there are twenty vertebræ, five of which are caudals and the rest dorsals. A smaller specimen, probably of *Eryops megacephalus*, has twenty-four vertebræ preserved in a continuous series, beginning with the atlas. The number of presacral vertebræ can be pretty definitely determined from these two specimens, and seems to be twenty-five or twenty-six. There are two sacrals and about fifteen caudals. The number of caudals is estimated from the anterior and posterior ones figured by Cope. These specimens furnish some new and interesting facts about the vertebræ of *Eryops*.

The atlas is composed of the neurocentra and intercentrum, the neurocentra resting firmly on the intercentrum, but not co-ossified with it. The intercentrum is not divided on the middle, as Cope

supposed.[1] The arch is small and bears no rib. The axis is composed of the same elements as the atlas, with possibly small pleurocentra in addition, but its arch is larger and bears a small rib. The rib seems not to have been attached to the intercentrum. The third cervical has small pleurocentra which support the arch. Posterior to the third the pleurocentra increase in size and push the intercentra far apart below. Toward the sacrum they again decrease in size and are pushed upward, finally resting on the intercentrum of the vertebra behind. The pleurocentra of the anterior caudals are reduced in size, and they gradually decrease caudad, until those of the distal caudals are very small. In the thoracic region the pleurocentra support the arch, but, as they become more and more reduced in size, the support is shifted more and more to the intercentrum, until in the caudals the latter forms the principal support. The intercentra are enlarged in the sacral and caudal regions, and those of the sacrum are opposed below.

The specimens that furnish these new facts are the ones from which Dr. Baur drew his conclusions, published in the November number of the *American Naturalist* of 1897. But Dr. Baur saw only three or four vertebræ free from the matrix. They were from the thoracic region, and his statements concerning them are accurate. The atlas was free from the matrix only on one side, and he says of it: "Only the first intercentrum is connected with the neural arches of the first vertebra, the atlas forming the atlas ring as in all Amniota."[2] The matrix still covered the vertebræ behind the atlas when the writer began work on them, and it was not then apparent that the second vertebra, like the first, has no pleurocentra in that specimen.

In the specimen figured by Cope the axis has no pleurocentra; but he does not mention this peculiarity in his description.[3] The intercentrum of the atlas was missing, and it was natural to suppose that the pleurocentra of both atlas and axis had been lost with it. But reference to his figure shows that there is little space for pleurocentra between the third intercentrum and the diapophysis of the axis arch. After examining Cope's specimen, the writer is not fully

[1] *Proceedings of the American Philosophical Society*, 1880, Vol. XIX, pp. 52, 56.

[2] *American Naturalist*, 1897, p. 978.

[3] *Proceedings of the American Philosophical Society*, Vol. XIX, Plate III, Fig. 5.

decided that pleurocentra were not present in the axis. There is a possibility that they have been lost in the specimens examined. Cope's figure also shows that the pleurocentra of the third cervical are very small. He figures no caudals except five proximal ones, in which the pleurocentra are greatly reduced and the intercentrum bears the arch, and five at the end of the tail, in which the intercentra are large and the pleurocentra very small.

The absence of the pleurocentra in the atlas and axis, and their reduction in the caudals, force the following conclusions: *Eryops* is not near the direct ancestry of the Amniota, because in all primitive Amniota the pleurocentra are large in the atlas and axis. On the contrary, the tendency is toward the development of true stereospondylous vertebræ, as in the Labyrinthodontidæ. The atlas and axis are composed of the same elements as in that form, and the caudals are approaching that type by the reduction of the pleurocentra. This conclusion was reached independently before the writer had read Jaekel's paper on *Archegosaurus*,[1] in which he reaches a like conclusion concerning the vertebræ of that genus, because of the great reduction of the pleurocentra in the caudals.

The problem of the homologies of the elements in the temnospondylous stegocephalian vertebræ has been much confused by misapprehension on the part of some authors, and by a lack of full information concerning the structure of this part of the skeleton of some of the forms that have been discussed most. The status of opinion to date is about as follows:

All writers are agreed that the neurapophyses are homologous with the neurapophyses of the Amniota. Gaudry[2] and Fritsch[3] believed that the intercentrum (hypocentrum) is the true centrum (pleurocentra) of the Amniota, while Cope, Baur, Albrecht, Dollo, and others maintain that it is homologous with the intercentrum of the Amniota. The evidence is overwhelmingly in favor of the latter view, and it is the one now generally accepted. But the homologies of the elements called pleurocentra and hypocentra pleuralia are

[1] *Zeitschrift der Deutschen geologischen Gesellschaft*, 1896.

[2] "Les enchainements du monde animal," *Fossiles primaires* (Paris, 1883).

[3] *Fauna der Gaskohle und der Kalksteine der Permformation Böhmens*, Vol. II (1889).

still in dispute. All are agreed that the posterior elements in the vertebræ of *Eryops* are homologous with the centrum of the Amniota, but Cope, Baur, and others believe that they are also homologous with the pleurocentra of *Archegosaurus*, *Actinodon*, and other temnospondylous stegocephalians; while Gadow holds that they are the hypocentra pleuralia of *Archegosaurus* and *Chelydosaurus*.[1]

These elements of *Eryops* are ventralia, not dorsalia, consequently not pleurocentra. They are interventralia enlarged and extending upwards. Consequently they are homologous with Fritsch's hypocentra pleuralia of *Chelydosaurus*, of the tail of *Archegosaurus* and homologous with the centra of the Amniota.

Cope, Baur, Albrecht, Dollo, and others believe that the hypocentrum pleurale is united either to the intercentrum[2] in front, or to the pleurocentrum[3] above in *Eryops;* or, as Baur puts it, "Das Hypocentrum pleurale trägt zur Vervollständigung des Wirbelkörpers bei."[4]

Jaekel has clearly shown[5] that in the caudal region of *Archegosaurus* the pleurocentra elongate and each separates into two elements, one above and one below, the lower being the hypocentrum pleurale (interventralia of Gadow). Probably no separation of this kind takes place in *Eryops*, since in the anterior caudals the pleurocentra are reduced and pushed high up by the close approach of the intercentra. A comparison of Figs. 14 and 15, and 16 and 17, shows how closely the vertebræ of *Eryops* resemble those of *Archegosaurus*. In the thoracic region there can be no doubt about the homology of the pleurocentra of the two forms. In the caudal region the evolution has progressed along different lines. In *Eryops* the hypocentra pleuralia do not separate from the pleurocentra, but both are reduced together; but the difference is not sufficient to raise a doubt about the homologies of the parts.

Dr. Hans Gadow calls *Eryops* a reptile on account of the structure of its vertebræ, but his conception of the vertebræ of this animal was wrong in several particulars. He based his conclusions on the

[1] *Philosophical Transactions of the Royal Society of London*, Vol. CLXXXVII (1896), p. 22.

[2] *Proceedings of the American Philosophical Society*, Vol. XVI, p. 245.

[3] *American Naturalist*, 1886, pp. 76, 77.

[4] *Biologisches Centralblatt*, Vol. VI, p. 333.

[5] *Zeitschrift der Deutschen geologischen Gesellschaft*, 1896.

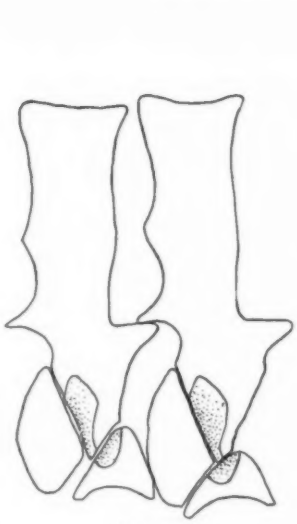

FIG. 14

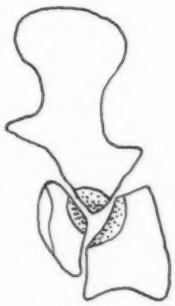

FIG. 15

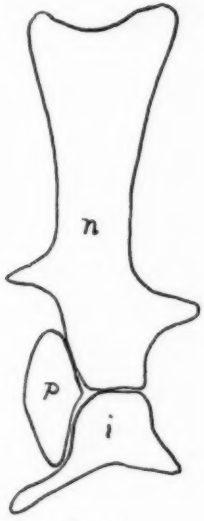

FIG. 16

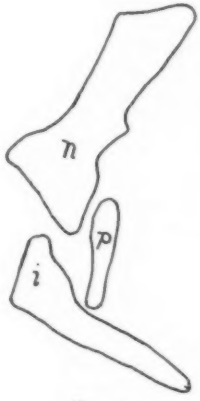

FIG. 17

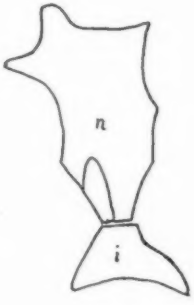

FIG. 18

FIG. 19

FIG. 14.—*Eryops* Cope; thoracic vertebræ; one-half natural size.

FIG. 15.—*Archegosaurus* Goldfuss; thoracic vertebra (after Jaekel).

FIG. 16.—*Eryops* Cope; anterior caudal vertebra; two-thirds natural size (after Cope).

FIG. 17.—*Archegosaurus* Goldfuss; caudal vertebra (after Jaekel).

FIGS. 18, 19.—*Eryops* Cope. Fig. 18, axis with top of arch missing; Fig. 19, atlas; one-half natural size.

i, intercentrum; n, neural arch.

literature on the subject, having examined very few specimens of the vertebræ themselves. He says: "The neural arches of the tail and thorax rest exclusively upon the posterior disk (pleurocentra of Cope)."[1] As already shown in the present article, the neural arches are gradually shifted on to the intercentra in the posterior part of the thoracic region, and in the caudals the intercentra furnish the greater part of the support. Dr. Gadow's figures[2] of two vertebræ in the British Museum shows that the neural arches rest against the intercentra in the dorsal region. Cope's figures[3] of the anterior caudals show that the intercentra form most of the support for the arches. (See Fig. 16.)

Dr. Gadow says:

> In the thoracic vertebræ the diapophyses of the neural arches alone carry the single-headed ribs. In the cervicals the articular facet extends downward and forms a shallow groove on the caudal portion of the intercentrum.[4]

In all of the thoracic vertebræ the rib is borne by both the arch and the intercentrum. The intercentra of the atlas and axis are the only ones anterior to the caudals that have no facet for rib articulation. The size of the rib facet on the intercentrum increases gradually posteriorly, and on the sacral vertebræ it is more than 2^{cm} in diameter. Furthermore the ribs are not all single-headed. As Cope has pointed out,[5] the sacral ribs are distinctly double-headed, though the capitulum and tuberculum are not widely separated. Five or six of the ribs just anterior to the sacrum have the capitulum and tuberculum separate, though not as distinctly as in the sacrals; and anterior to these the ribs are really double-headed, for they articulate with both the diapophysis and intercentrum.

Dr. Gadow says of the pleurocentra:

> They are, moreover, the pieces which, in *Eryops*, are attached to the caudal end of the cervical vertebræ, figured by Cope, and there actually and rightly called hypocentra pleuralia.[6]

[1] *Loc. cit., infra*, p. 21.

[2] *Philosophical Transactions of the Royal Society of London*, Vol. CLXXXVII, p. 41, Fig. 41.

[3] *Transactions of the American Philosophical Society*, Vol. XVI, Plate 1, Fig. 1.

[4] *Loc. cit.*, pp. 21. 22.

[5] *Palaeontological Bulletin*, No. 32, p. 15.

[6] *Loc. cit.*, p. 22.

Cope says that in some specimens a groove crosses the inferior side of the intercentra of the cervical region, and that the anterior part is probably the hypocentrum pleurale, but he does not figure vertebræ that have the groove. The pleurocentra are present in all of the vertebræ excepting the atlas and axis, and possibly the posterior caudals, and an examination of the specimens will convince the most skeptical that they represent the same elements throughout the column. But in some of the cervicals the other element, called by Cope hypocentrum pleurale, are present in the same vertebræ with the pleurocentra. How, then, can the hypocentrum pleurale be the pleurocentrum, when the pleurocentra are already represented in those vertebræ by other elements? The conclusion is obvious. The pleurocentra of *Eryops* are the interdorsalia of Gadow, and not the interventralia (hypocentra pleuralia), as he believes.

Recent investigations furnish almost positive proof that the homologies of the parts of *Eryops* vertebræ proposed by Cope are correct.

The neurapophyses (basidorsalia of Gadow) are homologous with the neurapophyses of other temnospondylous Stegocephalians and of the Amniota.

The intercentra (hypocentra, basiventralia of Gadow) are homologous with the intercentra of other temnospondylous Stegocephalians and of the Amniota.

The pleurocentra (interventralia of Gadow) are homologous with the pleurocentra (interdorsalia of Gadow) of other temnospondylous Stegocephalians and of the Amniota.

The hypocentra pleuralia (interventralia of Gadow) are homologous with the hypocentra pleuralia of *Archegosaurus*, *Chelydosaurus*, and *Sphenosaurus*.

In *Archegosaurus*, according to Jaekel,[1] the hypocentra pleuralia are united with the pleurocentra in the thoracic and anterior caudal regions. The fate of these elements in other temnospondylous Stegocephalians and in the Amniota is not known. They may be united with the pleurocentra, which seems the most probable; they may be united with the intercentra; they may have entirely disappeared; or all three of these conditions may be represented.

[1] *Zeitschrift der Deutschen geologischen Gesellschaft*, 1896.

Eryops Cope

Skull long, comparatively narrow; proportion of length to breadth about 9 to 7. Roof bones coarsely sculptured posteriorly, finely sculptured anteriorly. Nasals and premaxillæ very large; frontals excluded from orbits by junction of pre- and postfrontals. Pterygoids not meeting in the median line; parasphenoid dagger-shaped, tapering gradually to a point just in front of the palatine foramina; prevomers large. Orbits subcircular, situated in the posterior half of the skull; nares subovate, remote, at a considerable distance from the tip of the skull. Many minute denticles on pterygoids, palatines, prevomers, and parasphenoid. Teeth circular in cross-section, strongly ribbed near base, dentine strongly infolded. Three large teeth on each palatine. Mandible without postcotyloid process. Vertebræ rhachitomous. Ribs double headed. Pelvic bones coalesced.

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The investigations of the writer on *Eryops* and the Labyrinthodontidæ were carried on under the direction of Professor S. W. Williston, head of the department of vertebrate paleontology of the University of Chicago. The writer's sincerest thanks are due Professor Williston for the privilege of studying the specimens in Walker Museum, and for his valuable advice and encouragement. Thanks are also due to those in charge for permission to examine the specimens of *Eryops* preserved in the American Museum of Natural History of New York City.

RECENT GEOLOGY OF SPITZBERGEN

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The Spitzbergen archipelago consists of many islands upon a submerged plateau. The largest, known as West Spitzbergen, is not far from 300 miles long from north to south, and its southern point, South Cape, is in N. L. 76° 20′, about 150 miles north from the outlying Bear or Cherry Island. The western coast is indented by bays extending inland 20–80 miles. The surface, as seen from the western side, is a succession of plateaux, 300–900 feet near the coast, and rising to 1,600 feet farther inland, with irregular peaks, 2,000–4,000 feet high, scattered over it.

The climate of the region in middle Tertiary times was not more severe than that of our latitude, and familiar types of tertiary deciduous trees, described by Heer and later by Nathorst, occur abundantly at a locality about 8 or 10 miles south from Icefiord. The rainfall up to a comparatively recent period must have been abundant to bring about the baseleveling of the area and afterward to cut the deep valleys, filled in later times by the glaciers. The rainfall now must be insignificant, as during the very brief summer the temperature seldom rises above 4° C.

In West Spitzbergen, glaciers begin at a few miles north from South Cape and, at Horn Bay, several come down to the water, some of which seem to reach back to the inland ice north from that bay. On Recherche Bay, a branch of Bell Sound, and about 90 miles from South Cape, two fine glaciers remain: one on the west side coming down from Bell Mountain, 4 or 5 miles away, and another on the southeast, which extends southward to the high inland ice. Between these is a deep valley, in whose lower portion no ice remains. Northward to Icefiord, 20 or 25 miles, ice is present in notable quantity on the upland, but reaches into few of the valleys, many of which are open from the sea almost to the plateau. On the northwesterly side of Icefiord, a vast glacier, beginning at 6 or 7 miles from the sea, extends almost unbroken along the coast from Safe Harbor to Cape

Bohemian, about 25 miles, and stretches back, 12 to 20 miles, to a high ridge, where it may be continuous with the névé basin beyond. This glacier appears to be without a name; it should be dedicated to Nathorst.

The climatic conditions of Spitzbergen have undergone such change since the glacial period that for a long time the waste has exceeded the snowfall; evidence of loss is distinct everywhere. Bear Island, 150 miles south from South Cape, while in some respects harsher in climate than is West Spitzbergen, now shows no trace of glacial ice, though a fine trough coming down to sea-level at the northwest corner proves its former existence. Both glaciers in Recherche Bay project into the water with an abrupt face, estimated to be about 150 feet high, and fully one mile long in one, two miles in the other; but each of them is retreating on one side, where the boundary curves back on the shore and the surface is gently rounded. This retreat is especially marked in the western glacier, whose lateral moraine on the northerly side extends far out into the bay, while the moraine on the southerly side, medial between it and the greatly diminished middle glacier, is the hook behind which whalers have their anchorage. Even in the ice-wall the loss is notable; for on the face of the western glacier a great recess appears. A similar story is told by the vast Nathorst Glacier on Icefiord, whose retreat is especially marked on the westerly side near Safe Harbor; while between Bell Sound and Icefiord one sees along the coast the long trough-like valleys, almost wholly devoid of ice, but owing their form to the passage of glaciers. The presence of such fiord valley on the sides of Icefiord, as well as dying glaciers at the heads of that bay's branches, indicate that, at one time, confluent glaciers filled Icefiord and extended seaward. It is equally clear that the same condition existed on Bell Sound. So that the extensive glaciers of West Spitzbergen, like the small glaciers of Norway, must be regarded merely as remnants of a great sheet covering the whole land and extending, finger-like, through gorges into the sea.

The valleys are not broad, with gently rounded outline, like very many of those along Storfiord north from Marok, but they have abrupt walls, resembling those of the deeper interior fiords along the Norway coast. In some of the Norwegian valleys, especially along Storfiord, the glaciers have changed the form of the valleys far beyond

the usual trough, but such evidence of extended erosion is not distinct in those Spitzbergen valleys seen by the writer. Possibly the evidence is more satisfactory farther up those valleys where the floor becomes somewhat abrupt. On Advent Bay, just above a fragment of the terminal moraine forming the "hook" which protects the anchorage, there is a low wall of soft Jurassic rock rising sharply to about 20 feet above the water, and from its edge the floor reaches back to the bluff. This wall is somewhat higher than the marshy floor of Advent Dale, 3 miles away at the head of the bay. It seems strange that the ice did not remove this soft material. It is true that the movement could not have been rapid, as the slope of the floor is very gentle, and the place is less than a mile from the mouth of the bay where this glacier joined the main stream; but, unless the ice were heavily laden with débris, there should have been motion enough to cut away this petty obstruction.

There has been little erosion by water since the ice retreated, and the waste has been due to changes of temperature, which are superficial. The entry of the Spitzbergen Coal Company, about 200 feet long at the time of the writer's visit, was still in frozen coal. Summer heat thaws the ground to only a few inches, yet suffices to encourage growth of humble flowering plants, and an accumulation of peat, which makes tramping a matter of difficulty.

In the later Tertiary the surface of Spitzbergen must have been much nearer sea-level than now, to admit of the baseleveling which bears no relation to the position of the tilted, faulted, and contorted rocks, and which removed so much of the earlier Tertiary deposits. Comparatively rapid elevation must have succeeded, during which the deep valleys were digged out to be filled in later times by glaciers. Soundings reported on the English Admiralty Chart indicate that at one time the surface stood much higher than now. Possibly the later depression may be related in some way to the disappearance of the ice.

Northeast Land, a glaciated area of perhaps 20,000 square miles, forms with some outlying small islands the northern portion of the archipelago, and is separated at the southwest from West Spitzbergen by Hinlopen Strait. Westward from Northeast Land and its islands, the depth increases very slowly, the soundings showing 8–20 fathoms at 10–20 miles from the land; but the course of the valley of Hinlopen

Strait seems to be well marked, the depth increasing to 72, 90, and 200 fathoms, with 755 at 30 miles farther. As far as to the 200-fathom point high land is alongside, the depth being only 8–40 fathoms, while farther out toward the deepest sounding along the line of the strait the soundings eastward from that channel indicate a submerged dissected plateau.

Going westward 60 miles, one finds north from West Spitzbergen another area of soundings showing similar conditions. Wilde Bay extends southward from the north coast for 90 miles; forty miles up its depth is 30 fathoms; at 10 miles from the sea it is 90; but a submerged moraine reduces the depth at the mouth to 55–72 fathoms. Liefde Bay is just west, with, as its western boundary, a broad low area, about 100 square miles, apparently moraine stuff. At its mouth, where it adjoins Wilde, the depth is 93 fathoms. The course of the united bays can be followed northwestwardly until its depth becomes 150 fathoms, and at 15 miles farther 505. This is inclosed on the west by elevated land, covered by 42–70 fathoms and cut by valleys, some of which are tributary to the Wilde-Liefde, while others are tributary to a shallower valley at the west, which is but 360 fathoms deep at 10 miles west from the 505-fathom cast, and only 390 at 30 miles farther, or 120 miles northwest from Liefde Bay. Still farther west is a deeper valley with a depth of 235 at 27 miles, 300 at 40, and 730 at 115 miles from the northwest corner of the island.

Going southward along the west coast, one finds the long island known as Prince Charles Foreland, separated from West Spitzbergen by the narrow Foreland Sound, shallow and 8–10 miles wide. The depth of the sound at its mouth is 27 fathoms, but its course is clear, for the depth becomes 120 fathoms at 15 miles north. Westward from this the soundings are too few to be of much value, but the greatest depth at 75 miles from the coast is only 200 fathoms, though farther south the 300-fathom line is at 45 miles and the 500-fathom line at 51 miles from the coast. The abruptness of the change from 200 to 300 and then to 500 fathoms suggests that this line of soundings falls off into a valley.

Icefiord is much deeper than any of the bays at the north; it is 120 fathoms at 8 miles up, and 215 at its mouth, while at 60 miles west-southwest the soundings show 600 fathoms, though at a few miles north the depth is but 93–110 fathoms. At a few miles south,

due west from Bell Sound, the depth increases very gradually for 40 miles to 100 fathoms, but the course of the Bell Sound channel is in southwest direction, 839 fathoms being reached in 70 miles, and only 15 miles west from a line of soundings showing 90–130; a sounding of 160 fathoms between this line and the shore suggests the existence of a tributary valley there. West from South Cape the depth becomes 118 at 45, 523 at 55, and 743 fathoms at 65 miles.

Farther south the 700-fathom limit is between 60 and 70 miles west from a line joining South Cape and Bear Island; eastward from this line the depth decreases within 10–15 miles to about 200 fathoms, which is the depth on a broad strip of 10–15 miles; thence eastwardly for nearly 200 miles the depth, except along well-defined lines, varies between 20 and 50 fathoms. In 225 miles northeast from Bear Island the depth exceeds 35 fathoms only three times; while between this broad strip and the larger islands at the northwest one can trace deep channel-ways marking the westward drainage. An elevation of 250 feet would unite all the great islands to each other and to Bear Island, now 150 miles from South Cape, the nearest point.

The long channel-ways at the north traceable between walls until they reach a depth of 390 in one case, 505 in another, that of Icefiord traceable to 600 fathoms, with only 100 fathoms at 15 miles away on each side, as well as the relation of the 700-fathom line to the direction of the coast, seem to leave little room for doubt that at one time the coast line lay not far from that marked by the depth of 700 fathoms. The details of soundings do not permit anything further at present. Icefiord, now only 8 miles wide at the mouth, was a broad valley beyond the present coast line, 20 miles wide at 70 miles away, with its bounding walls rising 2,000–3,000 feet above its floor; the valley of Hinlopen Strait as well as that of Wilde-Liefde Bays must have extended in like manner to more than 100 miles beyond the present coast line; and the Spitzbergen plateau was a triangular area extending from beyond N. L. 82° southward to an unknown distance beyond Bear Island, not less than 700 miles from north to south; the width in N. L. 81° much exceeded that of the area given on the Admiralty Chart, which is about 400 miles wide. The writer had no access, during the preparation of this note, to the results obtained by the several recent expeditions to Franz Josef Land; but Nansen's description of the fiord features of the inlets

there, as well as the similarity in geological character between West Spitzbergen and a portion of Franz Josef Land, recognized by Nathorst, suggests that that area, now not more than 120 miles east from Northeast Land and extending northward to about 84°, may have been continuous with the Spitzbergen area, and may have reached as land far toward the North Pole.

Submerged moraines in many of the bays mark halts in recession of the ice. Where the branches of Red Bay on the north shore come together the depth decreases from 50 fathoms above to 6 and 7, with a narrow strip of 33 fathoms on one side; the depth increases to 78 farther down, but at the mouth of the bay is a bar with 8–23 fathoms. Near the head of Foul Bay the sounding is 61 fathoms, but at the mouth there is shallow water; Magdalena shows 50 fathoms near the head, but lower down it is blocked by shoals with about 30 fathoms on each side. Sassen Bay, the east branch of Icefiord, is 100 fathoms deep at 10 miles above its mouth, but is barred by a moraine with 49–63 fathoms. No such barring appears in Icefiord, which deepens steadily to 215 fathoms at its mouth; but the barring is distinct in Recherche Bay. Similar conditions exist at many other localities, and explain the absence of icebergs off the plateau. But in any case, the ice is not thick enough to give off imposing blocks, there being in all probability not more than 500 feet at any place where the wall comes down to the water.

That the great subsidence was succeeded by elevation—which may be going on—is proved by terraces in the moraine stuff on Icefiord and Recherche Bay, as well as at other localities along the coast. No opportunity was found for measuring these, but they are as characteristic as are those at Naes, Odda, and Marok as well as elsewhere in Norway. Sandy beaches were seen south from Icefiord.

The effect of wave-action is well shown on Bear Island, which has suffered severely on the east and west coasts. At one time a glacier had its origin on the southeasterly side and flowed to the northwest corner. The waves have cut away the névé area, and the trough is open at the east; as the coast on the westerly side is diagonal to the course of the trough, the bold rocky bluff at the southern point falls off northwardly until at the northwest corner the whole wall has been removed and the valley bottom is now the shore line.

THE NORTHERN AND SOUTHERN KINDERHOOK FAUNAS

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The name "Kinderhook," as applied to a series of Paleozoic strata in the Mississippi Valley, was first used by Meek and Worthen[1] in 1861 for all those beds lying between the "Black Shale" below and the Burlington Limestone above. The name of this series of formations was taken from the village of Kinderhook, in Pike County, Illinois, where a good exposure of beds of this age occurs in the Mississippi River bluffs. Another typical section, designated by the authors of the name, included the beds exposed at Burlington, Iowa, lying below the Burlington Limestone and extending downward to beneath the river level. Besides these, the "Lithographic Limestone," "Vermicular Shales," and "Chouteau Limestone" in Missiouri, as defined by Swallow and his assistants, were considered as the equivalents of the Kinderhook beds of Illinois and Iowa, as was also the so-called "Goniatite Limestone" of Rockford, Indiana.

The typical exposure of the Kinderhook Group, from which it has received its name, "is at the point of the bluff, just above the village of Kinderhook." The section at this place, as given by Worthen[2] and confirmed by the writer, is as follows:

5.	Loess capping the bluff	20 feet
4.	Burlington limestone	15 "
3.	Thin-bedded, fine-grained limestone	6 "
2.	Thin-bedded sandstone and sandy shales . . .	36 "
1.	Argillaceous and sandy shales, partly hidden . .	40 "

In connection with his description of the section at this locality, Worthen states that "the thin-bedded sandstones (bed No. 2) . . . . abound in fossil shells, belonging to the genera *Aviculopecten*, *Spirifer*, *Orthis*, and *Productus*, mostly identical with those from the grit

[1] *American Journal of Science*, Second Series, Vol. XXXII, p. 288.

[2] *Geological Survey of Illinois*, Vol. IV, p. 27.

stones at Burlington, which belong to the same horizon." Further than this, no description of the fauna of this typical Kinderhook section has ever been given.

The collection upon which the following list is based was made at the typical locality, the point of the bluff just above the village of Kinderhook. A few fossils were collected from the fine-grained limestone, bed No. 3, but they are so poorly preserved as to be scarcely identified with certainty. As indicated by Worthen in his original description of the section, the fossils occur most abundantly in the thin-bedded sandstones of bed No. 2. They do not, however, occur uniformly through this bed, but are restricted to a narrow horizon from 20 to 25 feet below the base of the fine-grained limestone, bed No. 3. The exact limits of this fossiliferous horizon have not been definitely determined because of the thickly covered talus slope, but it probably extends through not more than a foot or two of strata.

The fauna of this bed is of much interest, and the contained species will be briefly discussed in order.

1. **Orbiculoidea** sp. undet. A single specimen of this species has been observed. It is a brachial valve about 15^{mm} in diameter; the apex is excentric and is more than ordinarily sharp for members of this genus, the surface of the shell sloping away on all sides from the apex to the margin, with a concave curve.
2. **Crania**? sp. undet. This species is represented in the collection by a single depressed-convex internal cast of a subcircular shell about 12^{mm} in diameter. It is too imperfect to allow its relationships to be determined with accuracy, and its generic identification may be incorrect.
3. **Orthothetes chemungensis** Con. The species of *Orthothetes* which occur in the Kinderhook beds of the Mississippi Valley are so indefinitely characterized that it is exceedingly difficult to make satisfactory identifications. Several different species have been described by various authors, and some of them at least are doubtless good species. The species from Kinderhook are apparently identical with those from the Chonopectus fauna at Burlington, Iowa, which have been identified as *O. inaequalis* (Hall),[1] but all the specimens are probably distinct from the

[1] Weller, *Transactions of the St. Louis Academy of Sciences*, Vol. X, p. 66, Plate 1, Fig. 18.

typical form of *O. inaequalis*, and approach more closely to the *O. chemungensis* of the middle and upper Devonian faunas.

4. **Chonetes geniculatus** White. Several specimens of a small, finely marked *Chonetes*, although imperfectly preserved, seem to represent this species, which is typically a member of the Louisiana Limestone fauna.

5. **Chonetes** cf. **C. ornatus** Shum. In the original description of *C. ornatus* the typical specimens were said to be from the Chouteau Limestone of central Missouri, and from what is now known as the Louisiana Limestone of northeastern Missouri. The figures of the species, published with the original description, do not adequately illustrate the specimens from either of these localities. Extensive collections of more recent date have shown that the Chouteau Limestone and Louisiana Limestone specimens belong to distinct species, although both are characterized by the peculiar concentric markings upon which the species, as originally described, was mainly established. The Chouteau Limestone specimens prove to be identical with the species from the Kinderhook Oolite of Burlington, Iowa, which was described by Norwood and Pratton as *C. logani.* The Louisiana Limestone shell attains a larger size at maturity, is marked with coarser and more angular plications, and is usually proportionately broader than *C. logani;* and the name *C. ornatus* may be restricted to this species. The specimens from Kinderhook are all internal casts and do not well preserve the specific characters, but they seem to agree more closely with the specimens of *C. ornatus* from the Louisiana Limestone than with any other species. The specimens somewhat resemble those from the Chonopectus fauna from Burlington, Iowa, identified as *Chonetes* sp. undet.,[1] and they may be identical.

6. **Chonetes** cf. **C. illinoisensis** Wor. A third species of *Chonetes* occurs rarely in the Kinderhook fauna. It is larger than either of the others and is marked by finer radiating costæ, there being about 100 around the margin of a shell 15.5^{mm} broad. This shell has been identified provisionally with *C. illinoisensis*, as it has the general form and proportions of that species, and agrees more closely with it in all respects than with any other.

[1] Weller, *loc. cit.*, p. 69, Plate 1, Fig. 15.

7. **Productella** sp. undesc. This species is one of the more common members of the fauna, and is quite distinct from any heretofore described species of the genus from the Kinderhook faunas, from all of which it may be distinguished by its large size. It resembles some of the larger species from the Chemung beds of New York, but it is sufficiently distinct from any of them. Most of the specimens observed are more or less weathered, and in this condition some of the smaller individuals resemble weathered specimens of *Chonopectus fischeri*, the proportions of the two shells being much the same, but no authentic specimens of *Chonopectus* have been observed from this locality. The species has been named *P. sublaevis*, and a description with illustrations will be published elsewhere.
8. **Productus curtirostris** Win. This species, described from the Chonopectus fauna at Burlington, was, in a former paper,[1] referred to the brachial valve of *P. semireticulatus*. Additional specimens, however, studied since that paper was published, have demonstrated that the species was well founded, it being a remarkably depressed form of *Productus* of the *semireticulatus* type. The specimens from Kinderhook seem to be indistinguishable from those occurring at Burlington.
9. **Productus semireticulatus** Mart.? A species of *Productus* of the *semireticulatus* type, identical with the one so identified from the Chonopectus fauna at Burlington,[2] occurs in the fauna at Kinderhook. The only specimen representing the species is an external impression of the brachial valve which is scarcely different from similar specimens of *P. burlingtonensis* Hall, except that it is flatter. The pedicle valve also, as seen in specimens from Burlington, is not so strongly convex or ventricose as *P. burlingtonensis* from the Burlington Limestone.
10. **Productus** sp. undet. This species is represented by fragmentary specimens only, but, so far as can be determined, it is identical with the shells in the Chonopectus fauna at Burlington, formerly identified as *P. cooperensis* Swall.?[3] This identifica-

[1] Weller, *loc. cit.*, p. 70, Plate 1, Figs. 7, 8.

[2] Weller, *loc. cit.*, p. 70, Plate 1, Figs. 5, 6.

[3] Weller, *loc. cit.*, p. 71, Plate 1, Figs. 3, 4.

tion, however, is incorrect, the original *P. cooperensis* being a much smaller shell from the Chouteau Limestone of central Missouri, and entirely distinct from this one.

11. **Paraphorhynchus transversum** Weller. This shell is identical with a species in the Chonopectus fauna at Burlington, which has been identified as *Pugnax striatocostata* M. & W. var.?[1] but the species is sufficiently distinct from the typical form of *striatocostata*, it being proportionately much broader than that species and attaining a larger size at maturity.[2]

12. **Spirifer subrotundatus** Hall. The specimens of this species from the beds at Kinderhook are indistinguishable from those in the Chonopectus fauna at Burlington.

13. **Spirifer marionensis** Shum. This is one of the more common species of the fauna, and is of especial interest because it is identical with the shell so common in the fauna of the Louisiana Limestone of Missouri, which may be assumed to be the typical form of the species. The shells from the Chouteau Limestone and other Kinderhook formations of Missouri, excepting the Louisiana Limestone, as well as those from the Kinderhook beds Nos. 5–7 at Burlington, which have usually been identified as *S. marionensis*, are distinct from the typical Louisiana Limestone representatives of the species. This typical form may be recognized by its less prominent umbo, and by the more nearly obsolete fold and sinus, and although the Louisiana Limestone and Chouteau Limestone species are much alike, they are doubtless specifically distinct.

14. **Syringothyrus extenuatus** Hall. Most of the specimens of this species from Kinderhook are separate brachial valves which are more or less imperfect. A single specimen, however, preserves both valves in such a manner that the angle between the plane of the brachial valve and the cardinal area of the pedicle valve can be approximately measured. This angle is 38°, a little larger than the average angle of the specimens in the Chonopectus fauna at Burlington, which vary but little from 30°. It is, however, much closer to these Burlington specimens than to

[1] Weller, *loc. cit.*, p. 72, Plate 2, Figs. 16, 17.

[2] Weller, *Transactions of the St. Louis Academy of Sciences*, Vol. XV, p. 264.

the specimens of *S. hannibalensis* Swall., from the Louisiana Limestone, in which this angle does not vary much from 60.° In its flat cardinal area also the Kinderhook specimens agree with *S. extenuatus* rather than with *S. hannibalensis*, in which the area is usually more or less concave.

15. **Aviculopecten** sp. undet. A single imperfect specimen of a species of this genus has been observed. It is certainly distinct from any of the species in the Chonopectus fauna at Burlington, and may be an undescribed form.

16. **Pterinopecten** cf. **P. laetus** Hall. Several imperfect specimens of this shell have been observed, which are undoubtedly identical with those so identified from the Chonopectus fauna at Burlington,[1] although it is quite possible that they represent an undescribed species distinct from, but allied to, *P. laetus* Hall.

17. **Pernopecten cooperensis** Shum. This species has as yet not been recognized in the Chonopectus fauna at Burlington, but the Kinderhook specimens which have been observed are indistinguishable from specimens occurring in bed No. 5 in the Burlington section.

18. **Leiopteria undulata** M. & W. The type specimen of this species, described originally as *Pterinea? undulata*,[2] is said to have come from the Kinderhook at Burlington, Iowa. The authors of the species state, however, that they "have also seen some imperfect casts, very similar to this species, and possibly not distinct from it, from the same horizon, at Kinderhook, Ill. The latter are left valves, and seem to be a little more convex than in the typical examples." The specimens from Kinderhook mentioned by Meek and Worthen were undoubtedly the same as the specimens here under consideration. The species has not been seen by the writer from Burlington, but it doubtless occurs in the Chonopectus fauna at that locality. The figured type specimen is a very imperfect shell, showing parts of both valves; but, so far as it is preserved, it does not seem to differ in any marked degree from the specimens from Kinderhook.

[1] Weller, *Transactions of the St. Louis Academy of Sciences*, Vol. X, p. 83, Plate 3, Figs. 1, 2.

[2] *Geological Survey of Illinois*, Vol. III, p. 456, Plate 14, Fig. 5.

19. **Avicula strigosa** White. The specimens of this species from Kinderhook are all imperfectly preserved, but they seem to show no essential differences from the typical members of the species in the Chonopectus fauna at Burlington.
20. **Pteronites whitei** Win. A single very perfect left valve of this species occurs in the collection, and is indistinguishable from the members of the species in the Chonopectus fauna at Burlington.
21. **Goniophora jennae** Win. This is another Chonopectus fauna species, but it seems to be more common at Kinderhook than at Burlington. The specimens exhibit some variation, but in general they correspond quite closely with the smaller of the two type specimens figured by Weller.[1]
22. *Undetermined pelecypod.* This species is represented by two specimens of a small *Allorisma*- or *Grammysia*-like shell, too imperfect for identification.
23. **Sphaerodoma pinguis** Win. A single specimen in the collection is apparently identical with this species which was originally described from the Chonopectus fauna at Burlington.
24. **Straparollus** sp. undet. A small specimen too imperfect for identification.
25. **Bellerophon** sp. undet.
26. **Patellostium scriptiferus** White. The specimens of this species from Kinderhook are identical, in all their essential characters, with the typical representatives of the species from the Chonopectus fauna at Burlington.
27. **Brachymetopus** sp. undet.

The most noticeable feature of this fauna is its striking similarity to the Chonopectus fauna at Burlington, although the total number of species recognized is much smaller, and the most characteristic species at Burlington, *Chonopectus fischeri*, has not been noticed at Kinderhook. In spite of the absence of this species, however, the fauna can be definitely stated to be equivalent to the fauna of the yellow sandstone at the summit of bed No. 2 at Burlington, and doubtless this yellow sandstone at Kinderhook and the yellow sandstone at Burlington would be found to be a continuous forma-

[1] *Loc. cit.*, Plate 3, Fig. 14.

tion, if the outcrop could be traced through the intervening area. This correlation is of especial interest, because it assists in tying together the Kinderhook faunas at Burlington with those of northeastern Missouri, which are separated by the synclinal folding of the strata which carries the beds far beneath the surface in the area between.

The presence in the fauna of numerous specimens of *Spirifer marionensis*, of the typical form occurring so abundantly in the Louisiana Limestone, is another factor of great importance. This species is entirely absent from the Chonopectus fauna at Burlington, nor is it represented by any species at all closely allied to it. In the Burlington section no species of *Spirifer* likely to be confused with *S. marionensis* occurs except in the higher beds, Nos. 5 and 6, and this species, although it has usually been identified with *S. marionensis*, is believed to be a distinct form, which in Missouri occurs only in the Chouteau Limestone or its equivalents, and in beds lying above the Louisiana Limestone. Other species which are common to the Louisiana Limestone fauna and the one under consideration are *Chonetes geniculatus* and probably *Chonetes ornatus*, and of these one, *C. geniculatus*, and perhaps also the other, are recognized in the Chonopectus fauna at Burlington.

Although the relationships between this fauna from Kinderhook and the Louisiana Limestone fauna are far less striking than between the fauna at Kinderhook and the Chonopectus fauna at Burlington, yet it is believed that they are all but different facies of one fauna, the Louisiana Limestone expression being characteristically the limestone facies, while the Chonopectus fauna at Burlington represents the arenaceous facies. Another point bearing upon the correlation is the presence in the Louisiana Limestone of one of the commonest and most characteristic pelecypod species of the Chonopectus fauna, viz., *Grammysia plena* Hall.[1]

In the sections at both Kinderhook and Burlington there is a bed of fine-grained, more or less fragmental limestone, resembling in a marked degree the Louisiana Limestone of Missouri at Hannibal and Louisiana. On the Mississippi River the Louisiana Limestone

[1] A specimen of this species has been seen by the writer in the collection of Professor R. R. Rowley, of Louisiana, Missouri.

attains a maximum thickness of 60 feet, but at Kinderhook the limestone layer above the yellow sandstone is but 6 feet in thickness, while at Burlington it has a maximum thickness of 18 feet. At Kinderhook this limestone is but sparsely fossiliferous, although one of the species recognized, *Productella pyxidata*, is one of the commonest members of the Louisiana Limestone fauna. At Burlington, Iowa, the fauna of the limestone (beds Nos. 3 and 4) above the yellow sandstone of bed No. 2 contains a modified facies of the Chonopectus fauna. *Chonopectus fischeri* is a common species, and associated with it is *Paraphorhynchus striatocostatum*, which sometimes occurs abundantly. This species was originally described from Kinderhook, and, judging from the lithologic characters of specimens from Pike County, Illinois, in the collection of Walker Museum, it occurs in the fine-grained limestone above the yellow sandstone. The same species, in its typical form, has been collected by Professor Rowley in the Louisiana Limestone.[1] Another species binding the fauna of the fine-grained limestone at Burlintgon to that of the Louisiana Limestone is *Syringothyris halli* Win., which is apparently but a small form of *S. hannibalensis* so characteristic of the Louisiana Limestone. Both of these species are distinct from, but closely allied to, the species of the same genus occurring in the yellow sandstone beds at both Burlington and Kinderhook, and known as *S. extenuatus* Hall.

The interrelationships of the various expressions of the Louisiana-Kinderhook-Burlington faunas under discussion are such as to make their correlation a matter of some certainty. It may be assumed that we have to deal here with one general contemporaneous formation, exhibiting at Louisiana and elsewhere on the Mississippi River a limestone facies throughout, while east and north, at Kinderhook and Burlington, the sediments were largely arenaceous, the conditions for the deposition of calcareous sediments not being introduced until near the close of the time epoch represented.

Another factor which adds to the strength of the correlation of

[1] The writer has not seen a specimen from the Louisiana Limestone, but Professor Rowley states that he has collected a very perfect specimen, which is no longer in his collection. Hall and Clarke also illustrate a specimen of this species (*Paleontology of New York*, Vol. VIII, Part II, Plate 60, Figs. 33, 34.) from Pike County, Missouri, which doubtless came from the Louisiana Limestone.

the Louisiana Limestone with beds No. 2–4 at Burlington is afforded by the identity of the faunas of the superjacent beds in both regions. The fauna of beds Nos. 5 and 6 are modifications of one and the same organic assemblage, which exhibits characteristics totally different from those of the faunas below. This fauna of the upper beds of the Kinderhook section at Burlington is characterised by such genera of pelecypods as *Macrodon*, *Palaeoneilo*, *Promacrus*, and *Crenipecten*, and by the brachiopods *Chonetes logani*, *Lepaena rhomboidalis*, and *Spirifer* sp. allied to *S. marionensis*, but distinct from it. The whole expression of the fauna is entirely different from that of the beds below. In the vicinity of Louisiana this same fauna of the upper beds at Burlington is well exhibited in the yellow, vermicular, arenaceous beds near the summit of the Hannibal Shales, which overlie the Louisiana Limestone.

At Kinderhook the conditions are somewhat different, no evidence of the presence of the higher fauna having yet been found. At this locality the fine-grained limestone bed is apparently followed immediately by the typical Burlington Limestone, bearing the typical fauna of that horizon.

In tracing the further distribution of the fauna of the yellow sandstone of Kinderhook and Burlington, it is found to occur 60 miles northwest of Burlington, in Washington County, Iowa, at Maples' Mill on English River, near Wellman. At this locality a yellow sandstone similar to that at Burlington has been called the "English River Grit" by Bain.[1] The fauna of this bed is rather extensive, and contains the following species:

1. **Scalarituba missouriensis** Weller. Some portions of this Sandstone are perforated by meandering burrows with transverse concave ridges which are in every way similar to those in the Hannibal and Northview Sandstones of Missouri.
2. **Orthothetes** sp. The specimens of this genus from the English River Grit are larger and more numerous than those of the Chonopectus Sandstone at Burlington. They may perhaps be identified as *O. chemungensis* Hall; at least they are closely allied to that New York Devonian species.

[1] *American Geologist*, Vol. XV, p. 322; *Iowa Geological Survey*, Vol. V, p. 134.

3. **Schizophoria** cf. **S. swallovi** Hall. This species is represented in the collection by a single specimen. It is specifically identical with the species in the Chonopectus Sandstone at Burlington, which has been referred to *S. swallovi*. The condition of preservation of neither the Burlington nor the English River specimens is sufficiently good to make such an identification absolutely certain, but they seem to agree more closely with that Burlington Limestone species than with any other.
4. **Chonopectus fischeri** (N. & P.). This species, which is so characteristic of the fauna at Burlington, is present in the English River Grits, but is much less common.
5. **Productus laevicostus** White. This *Productus* is one of the less common species of the fauna, but it differs in no essential respect from specimens occurring elsewhere.
6. **Productus curtirostris** Win.
7. **Productus** 2 or 3 undet. species.
8. **Productella concentrica** Hall. Several specimens of this species are present in the collection from English River, which are indistinguishable from examples occurring in the faunas of beds Nos. 5 and 6 at Burlington, but the species has not been observed at the latter locality in the Chonopectus Sandstone.
9. **Productella nummularis** (Win.). This is one of the common species in the English River fauna, while at Burlington it is rare. Individuals from the two localities agree closely in all essential respects.
10. **Paraphorhynchus transversum** Weller. This is a rare species in the English River fauna, but the specimens differ in no essential characters from those occurring at Burlington and Kinderhook.
11. **Rhynchonella**? sp. A single specimen too imperfectly preserved for recognition.
12. **Eumetria altirostris** White. In the English River fauna this species grows to a larger size and is much more abundant than in the Chonopectus Sandstone at Burlington.
13. **Athyris corpulenta** (Win.). This species is much more common in the English River fauna than at Burlington, but none of the specimens observed are perfectly enough preserved to admit of

the correct generic reference of the species. It undoubtedly is not an *Athyris*, but it may be allowed to remain in that genus until more definite knowledge of its characters can be gained.

14. **Spirifer** sp. undesc. This is a peculiar, elongate, narrow species, whose shell is plicated throughout. It has been named *S. maplensis*, and a description with illustrations will be published elsewhere.
15. **Spirifer biplicatus** Hall. This species is not uncommon in the fauna, the individuals not differing essentially from Burlington specimens. The species is remarkable because of its exceedingly elongate hinge-line, produced in long mucronate extensions.
16. **Syringothyris extenuatus** Hall. A single brachial valve, of rather large size, is the only representative of this species in the collection. It agrees perfectly with similar specimens from the Chonopectus Sandstone at Burlington.
17. **Aviculopecten**? sp. undet. A single imperfect specimen of a very large Aviculopecten-like shell is preserved in the English River collection. When complete, its breadth must have been 100^{mm} or more, but its state of preservation is such as will not admit of definition.
18. **Pernopecten cooperensis** Shum. Several more or less imperfect specimens are present in the collection, which may be certainly identified with this species. The species has not been certainly recognized in the Chonopectus fauna at Burlington, but it occurs rarely at Kinderhook. It is especially characteristic of the Kinderhook faunas of central Missouri and of the higher Kinderhook faunas at Burlington.
19. **Leiopteria spinalata** (Win.). A single imperfect specimen of this species has been observed from English River. Its characters are not well shown, but it appears to be identical with the Burlington shells.
20. **Leiopteria** sp. undesc.
21. **Pteronites whitei** (Win.). A single small specimen from English River seems to belong to this species. Its extreme length is only 15^{mm}, but it agrees in all essential characters with the larger shells from Burlington and Kinderhook, and may be safely considered as an immature individual.

22. **Mytilarca occidentalis** W. & W. The specimens of this species in the English River fauna are similar to those of the Chonopectus fauna at Burlington.
23. **Goniophora jennae** (Win.). The English River specimens of this species are identical with the larger one illustrated from the Chonopectus fauna at Burlington. The smaller specimens from that locality should probably be separated from *G. jennae* as a distinct species, to which the Kinderhook, Illinois, shells should be referred.
24. **Macrodon cochlearis** Win. This is one of the common species of the fauna, and the specimens do not differ essentially from the Burlington examples.
25. **Grammysia plena** Hall. A single imperfect left valve of this species has been observed, but its identification with the Burlington specimens is entirely satisfactory.
26. **Sphenotus iowensis** (Win.). Specimens of this species from English River are similar to those from Burlington in all essential characters.
27. **Sphenotus** sp. undet.
28. **Murchisonia** sp. undet.
29. **Naticopsis depressa** Win. The "fine regular elongate nodes," mentioned in the original description of this species as marking the upper ends of the striæ of growth, could not be detected upon either of the two specimens marked as types in the University of Michigan collection, and no others from Burlington have been studied by the writer. Two specimens from English River, however, show this characteristic nicely, which leads to the supposition that all of the type specimens used by Winchell in the description of the species are not preserved in the collection at Ann Arbor.
30. **Straparollus** sp. undet. This is a rather common species in the fauna, but it is usually not well preserved. It resembles *S. angularis*, but does not have the angular revolving ridge of that species.
31. **Bellerophon bilabiatus** W. & W. This species, which is one of the commonest ones in the Chonopectus fauna at Burlington, is likewise a common species in the English River Grit.

32. **Bellerophon vinculatus** W. & W. This species is much more common at English River than at Burlington.

33. **Bellerophon** sp. undet. Two undetermined species of this genus are recognized in this fauna, one or both of which are probably undescribed.

34. **Euphemus** sp. undet. Two species of this genus occur in the English River fauna, both of which are probably undescribed. The genus has not been observed in the Chonopectus fauna at Burlington, and heretofore it has been described from the Kinderhook only in the faunas of central and southwestern Missouri.

35. **Porcellia obliquinoda** White. A single fragment of a shell of this species has been observed from English River, but, so far as it is preserved, it is essentially similar to specimens from the Chonopectus fauna at Burlington.

36. **Dentalium grandaevum** Win. This species, which is present in the Chonopectus fauna at Burlington, and also in the fauna of the upper yellow sandstone (bed No. 5) at the same locality, is represented by numerous fragments in the English River fauna.

37. **Orthoceras whitei** Win. A single imperfect fragment of this species has been observed, but it is sufficiently well preserved to make its identification certain.

38. **Orthoceras heterocinctum** Win. This species is somewhat more common than the last, but it is always preserved in a fragmentary condition.

39. **Phragmoceras expansum** Win.? A fragmentary specimen is identified with a query as this species, but too little of the specimen is preserved to make the identification certain.

40. Fish remains? Eastman[1] has called attention to some small, peculiar, bilobed bodies from Burlington, where they occur in the Chonopectus Sandstone, which are probably icthic in nature, but their systematic position cannot even be guessed. Similar specimens occur in the English River Grit, although they seem to be specifically distinct from the Burlington specimens. Occurring as they do in this fauna at distant localities, it becomes a matter

[1] *Journal of Geology*, Vol. VIII, pp. 36, 40.

of convenience to be able to refer to them by name, and therefore I propose for them the generic name *Idiodus*. The Burlington species may be called *I. eastmani*, and the English River species *I. biloba*.

This fauna of the English River Grit is essentially that of the Chonopectus bed at Burlington, but with certain modifications. *Chonopectus fischeri*, although present in the fanua, is not one of the most abundant species; in fact, although most of the species at Maples' Mill can be identified with Burlington forms, many of those that are common at Burlington are rare on English River, and, *vice versa*, rare species at Burlington are in several instances more common on English River.

In Marshall and Tama Counties, Iowa, in the region of Le Grand, 120 miles northwest of Burlington, the entire Kinderhook section is not exposed. Several beds of limestone have been quarried extensively, and have afforded an abundance of fossils, the best-known of which are the famous Le Grand crinoids. The faunas of all these limestone beds are closely allied to that of the higher beds at both Burlington and Louisiana. Beneath these limestones, of which the lowest is a white oolite, there is a 20-foot bed of blue argillaceous sandstone[1] rarely exposed, which at Indiantown, about two miles east of Le Grand, is said to be very friable and of a yellowish tone due to weathering.[2] At this latter locality casts of fossils are said to occur, and although none of them have come under the observation of the writer, yet it seems quite possible that they may represent the Chonopectus fauna, and they should be carefully examined with that point in view.

The known distribution of the arenaceous facies of the Kinderhook fauna under discussion extends along a line having a general northwest-southeast direction, from Kinderhook, Illinois, to Burlington, Iowa, and thence to near Wellman, Iowa—a total distance of nearly 140 miles. If the fauna of the bluish or yellowish sandstone near Le Grand should prove to be the same, 60 miles more would be added to its northward distribution.

The outcrop of the limestone facies of the formation, with its

[1] Beyer, *Iowa Geological Survey*, Vol. VII, p. 222.

[2] *Ibid.*, p. 223.

characteristic fauna, extends from near Hannibal, Missouri, nearly 60 miles to Hamburg, Illinois, where there are about four feet of strata referable to this formation, carrying the typical fauna as seen at Louisiana. The entire distribution, therefore, of both the arenaceous and calcareous facies of this Kinderhook fauna extends along a comparatively straight line for 200 or 250 miles.

The distribution of the beds carrying the fauna, which at Burlington and Louisiana is confined to the higher beds of the Kinderhook section, is quite different from the distribution of the beds just discussed. This fauna has its most characteristic expression in the Chouteau Limestone of central Missouri, especially in Pettis and Cooper Counties. At Pin Hook Bridge over Muddy Creek, 10 miles northeast of Sedalia in Pettis County, there are 60 feet or more of Chouteau Limestone, usually of a bluish-gray color, sometimes yellowish, and sometimes arenaceous or cherty. This limestone rests with apparent conformity upon limestones which are of Devonian age, as indicated by the fossils. Lying above the Chouteau Limestone is the Burlington Limestone, whose lower beds in this county contain a fauna identical with the lower beds of the same formation at Burlington, Iowa. At Sweney, 15 miles north of Sedalia on the Missouri, Kansas & Texas Railroad, a large quarry has been opened in the Chouteau Limestone, exposing about 60 feet, with probably the same Devonian limestone beneath it, and the Lower Burlington Limestone above it, as at the Pin Hook section. At neither of these sections have the details of the distribution of faunules been studied out, but the fauna as a whole bears the same expression as the fauna of the uppermost beds at Burlington and Louisiana, although at Burlington the beds bearing this fauna do not exceed 11 feet in thickness, more than half of which is a yellow sandstone,[1] and at Louisiana the fauna, so far as observed, is restricted to Keyes bed No. 8, 12 feet of brown sandy shale.[2] Furthermore, at no locality in central or southern Missouri has any trace of the Chonopectus fauna of the Burlington section been observed, nor of the fauna of the Louisiana Limestone.

In southwestern Missouri the same Chouteau fauna occurs that

[1] Bed No. 7, the soft, buff, gritty limestone at Burlington, is not here included, as its fauna is much more closely related to that of the overlying Burlington Limestone.

[2] *Missouri Geological Survey*, Vol. IV, p. 47.

is present in central Missouri, but the beds containing it do not constitute one continuous limestone formation. Instead, three distinct formations are recognizable in Green County. The lowest of these is a limestone identical in lithologic characters with the lower beds of the Chouteau Limestone of Pettis County, and carries essentially the same fauna.[1] Its thickness may be estimated at about 10 feet, and it may be considered as the thinned edge of the Chouteau Limestone lens.[2] The second member occupying the Kinderhook interval in Green County has been called the Northview,[3] and corresponds with Shepard's Hannibal Shale, except that the limestone at the base is excluded as noted above. In its lithologic characters this formation is essentially identical with the Hannibal Shale and Sandstone lying above the Louisiana Limestone in northeastern Missouri, and the faunas of the two formations are related. However, the Northview and the Hannibal do not constitute one continuous formation, the entire interval in central Missouri being occupied by the Chouteau Limestone. The highest Kinderhook bed in Green County is the Pierson Limestone.[4]

In northern Arkansas all the Kinderhook beds, so far as they have been examined, are characterized by the faunas related to that of the Chouteau Limestone. In southeastern Missouri, Kinderhook beds are well exposed in the Mississippi River bluff near Sulphur Springs and Kimmswick, and elsewhere in Jefferson and St. Louis Counties. The most characteristic fauna in this region occurs in a red calcareous shale. The fauna is peculiar in some respects, but its affinities are with the Chouteau faunas of central and southwestern Missouri, and not at all with the Louisiana-Chonopectus fauna; this fauna is recognized as far north as southern Jersey County, Illinois.

[1] In an earlier paper ("Correlation of the Kinderhook Formations of Southwestern Missouri," *Journal of Geology*, Vol. IX, pp. 130–48) this lowest bed of the Kinderhook section in Green County was taken to be identical with Shepard's Sac Limestone. This was an error, as further investigation has shown. The Sac Limestone lies beneath this Kinderhook limestone, the Phelps Sandstone with its *Ptyctodus* fauna being between. This lowest limestone of the Kinderhook interval was given but little mention by Shepard in his *Green County Report*, being included in his Hannibal Shales. On p. 87, he speaks of these lower harder beds being used for curbing, etc., and on p. 202 he mentions these beds as the Hannibal limestone.

[2] For the fauna of this bed see *Journal of Geology*, Vol. IX, pp. 136, 137.

[3] Weller, *Journal of Geology*, Vol. IX, p. 140. [4] Weller, *loc. cit.*, p. 144.

At a distance from the Ozark region, the Chouteau fauna is recognized in the Goniatite Limestone of Rockford, Indiana, where the Cephalopod genus *Prodromites* occurs, the further distribution of this genus being in the Chouteau Limestone of Pettis County, Missouri, and in the higher beds at Burlington. In certain portions of the Waverly of Ohio, Kentucky, and Indiana characteristic elements of the same fauna may be recognized. In still another direction this fauna occurs in the limestones of the higher portion of the Kinderhook beds in Marshall County, Iowa, and in the Wassonville limestone of Washington County, Iowa.

From a detailed consideration, therefore, it is seen that the Kinderhook strata of the Mississippi Valley region contain two distinct faunal assemblages, each of which shows modifications into various facies. During earlier Kinderhook time these two faunas were restricted, one to the more northern, the other to the more southern region, and the two Kinderhook provinces were separated by some barrier, doubtless a land barrier. Near the close of the Kinderhook epoch, the barrier separating the two provinces was removed, and the fauna from the south migrated into the northern province. The northern fauna, however, probably continued to live in a more and more restricted area to the close of Kinderhook time, since at Kinderhook, Illinois, there is apparently no evidence of the presence of the southern fauna in any beds between those bearing the typical northern Kinderhook fauna and the base of the Burlington limestone. With the removal of the barrier, however, the northern fauna did not make any headway into the southern province.

THE DEVELOPMENT OF SCAPHITES

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Manila, Philippine Islands

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INTRODUCTION

The material used in this study is that of the Paleontological Collection of Leland Stanford Junior University, and includes material collected from two very different localities.

In 1900 Mr. Milnor Roberts collected, in the vicinity of Sand Springs, thirty miles north of Wibaux, Mont., a suite of fossils, the majority of which were *Scaphites*. The rock is a dark, very hard and compact limestone, and contains the following genera and species:

Scaphites nodosus
Scaphites nodosus var. brevis
Scaphites nodosus var. plenus
Scaphites nodosus var. quadrangularis
Scaphites mullananus

With these occurred:

Nautilus dekayi
Inoceramus barabini
Inoceramus sagensis
Antalis ————
Volsella meekii
Baculites ovatus
Pyra[sus (Neptunella) subturritus
Protocardia salinaensis (?)
Protocardia rara
Neæra ventricosa

All of these, and many more, are figured in the reports of the Hayden Survey of the Territories, and by Stanton,[1] and referred to the Fort Pierre horizon of the Upper Cretaceous.

Stanton records a similar fauna from the Cretaceous rocks of Nebraska, where the following species are contained in dark gray and bluish plastic clays:

Nautilus dekayi	*Dentalium graciale*
Placenticeras placenta	*Crassatella evansi*
Baculites ovatus	*Cuculala nebrascensis*
Scaphites nodosus	*Inoceramus sagensis*
Inoceramus nebrascensis	*Inoceramus vanuxemi*
Bones of *Mosasaurus missouriensis*	

The beds also occur on Sage Creek, Cheyenne River, and on White River above the Mauvaises Terres in South Dakota. Mr. Stanton also states that these same beds are exposed in central Colorado and contain:

Nautilus dekayi	*Sphenodiscus lenticulare*
Baculites ovatus	*Scaphites nodosus*
Baculites compressus	*Ptychoceras mortoni*
Inoceramus cripsii	*Heteroceras* (several specimens)
Inoceramus proximus	*Anisomyon*
Placenticeras placenta	*Lucina occidentalis*
Avicula linguiformis	*Avicula nebrascensis*, etc.

Clearly, then, the suite from Montana belongs to the Fort Pierre horizon of the Upper Cretaceous, and is, as far as we know, confined to that horizon only. *Scaphites nodosus* certainly is characteristic of that horizon.

The other group of Scaphites is from the Pacific coast province and from the horizon known as the Lower Chico, Upper Cretaceous. The specimens I have used were collected and described by Mr. F. M. Anderson,[2] paleontologist for the California Academy of Sciences, from the '49 mine near Phœnix, Ore.

These occur in soft, yellowish sandstone, with the following characteristic fossils:

[1] T. W. Stanton, *The Colorado Formation and its Invertebrate Fauna*, 1893, Bulletin No. 106, U. S. Geological Survey.

[2] F. M. Anderson, "Cretaceous Deposits of the Pacific Coast," *Proceedings of the California Academy of Sciences*, 3d series (1902), Vol. II, No. 1.

Desmoceras hoffmani	*Placenticeras pacificum*
Desmoceras sugatum	*Schœnbachia oregonensis*
Desmoceras ashlandicum	*Arethusa californica*
Baculites chicoënsis	*Nautilus sp.* (?)
Helicoceras breweri	*Scaphites inermis*
Helicoceras declive	*Scaphites condoni*
Ancyloceras lineatum	*Scaphites gillesi*
Lytoceras sacya	*Scaphites perrini*
Lytoceras jackonense	*Scaphites roguensis*
Lytoceras jukesi	*Scaphites klamathensis*

The first two in the list of *Scaphites, S. inermis* and *S. condoni,* have been selected for study principally for the reason that there was more material of these two species available for the work.

In connection with these the following have been studied:

Sonneratia stantoni
Desmoceras beudanti
Desmoceras hoffmani
Lytoceras alamedense
Baculites chicoensis
} chiefly from the papers by J. P. Smith.[1]
Pachydiscus

All drawings have been made with the camera lucida, either with or without the microscope.

The very young stages have in most cases been enlarged thirty diameters, and some of the larger adolescent stages only ten, while the adults are represented at natural size.

The writer wishes to express his appreciation of the valuable aid, in the matter of suggestions and in furnishing some excellent material to work on, rendered by Professor J. P. Smith. Acknowledgments are also due Professor Stuart Weller for valuable assistance and opportunity extended to the writer to examine material from the Upper Cretaceous of New Jersey.

DESCRIPTION OF SPECIES

The writer does not feel called upon to add to or repeat the description of these forms as found in Meek's or Anderson's works, more than to state just enough to aid the reader and save him the trouble of referring to these larger works.

[1] J. P. Smith, "Development of Pytoceras and Phylloceras," *Proceedings of the California Academy of Sciences,* 3d series, Vol. I, No. 4; "Larval Coil of Baculites," *American Naturalist,* Vol. XXXV (1901), No. 409.

Scaphites nodosus Owen is by far the largest Scaphite of those mentioned in this paper. It is, like all of the *nodosus* group, coarse-ribbed in the neanic and ephebic stages, growing more smooth on the abnormal body chamber where the coil leaves the true spiral. It has strong nodes on the ventral shoulders, and sometimes also on the umbilical shoulders. The form is quite robust and is remarkable for its long, last body chamber which has left the whorl partly and turned back on itself somewhat as in the case of *Macroscaphites*, though not so pronounced.

Scaphites nodosus brevis is coarse-ribbed, but shows no nodes on the umbilical shoulders, and is a much smaller form, less gibbous, and just beginning to leave the coil. *S. nodosus plenus* is simply a very gibbous form, with about the same dimensions as *brevis*. Its suture in the adult is somewhat different, and the nodes are not so pronounced. *S. nodosus quadrangularis* can be distinguished from *brevis* only by its flattened dorsum and the very small nodes on the umbilical shoulders.

S. mullananus is slightly smaller than the others, and, as far as the writer can determine, does not leave the coil at all, and possesses no abnormal body chamber. Nodes are altogether lacking, the ribs coarse and passing from umbilicus to umbilicus.

The two Oregon species are very much smaller than those mentioned above, flatter, and almost devoid of ornamentation. At the very end of the last coil there is a slight departure from the coil and a constriction around the coil just back of the aperture. The largest of these would not be more than 15^{mm} in diameter. *Scaphites condoni* has a slight wrinkling or development of ribs on the side of the adult coil, but no nodes. *S. inermis*, on the other hand, possesses a row of very small nodes on the ventral shoulder or the last coil. They are both extremely thin forms.

S. nodosus Owen, which is not shown in the plate, measures about $3\frac{1}{2}$ inches in diameter along its longest axis; *S. nodosus brevis* and the others, about 2 inches and less. They all have narrow umbilici. This is quite the opposite from what we find in the Oregon species.

DISTRIBUTION

The type of this comprehensive genus was first found in Dorsetshire, England, by Parkinson,[1] in the year 1811. *Scaphites*, however,

[1] Parkinson, *Organic Remains*, Vol. III, p. 145, Pl. X, Fig. 10.

is well known from many parts of Europe and also India. Logan[1] thinks that all known *Scaphites* originated from one species in the Gault of Europe, the Gault being transitional from the Lower to the Upper Cretaceous, and have migrated from Europe to India and to America. At that time he thought *Scaphites* monophyletic, but the recent discovery by Mr. Anderson in the Upper Cretaceous of Oregon and California of some new scaphite forms with different ontogeny, and mingled with an entirely different fauna, makes it highly improbable that this is so.

According to Anderson,[2] there was probably a communication established between the Interior Sea of America and the Pacific province in Upper Cretaceous time, but none up to that time, unless we go back of the Jurassic. However, J. P. Smith[3] has shown that there was a connection between the Indian province and the west coast of America. An examination of the plates in the volume on the Cretaceous fauna of India reveals a striking similarity between the Indian *Scaphites* and those in the Pacific province.

On the other hand, the fauna of the western Interior Sea is known to be very similar to, if not identical with, faunas in just the other direction. The writer has seen some *Scaphites* from the Upper Cretaceous of New Jersey in Professor Stuart Weller's collection which appeared to be of the same type as those coming from Montana. Much the same fauna has been described from Texas and Alabama. This seems to make it quite conclusive that migration took place along the Cretaceous coast line from the eastern border around by the Mississippi embayment up into the interior. Having got as far as the Atlantic coast, we can explain the migration from western Europe in much the same way as the migration from the Indian province to western America.

As the writer will attempt to show, the ontogenetic study of the forms from the two regions, west coast and interior, simply corroborate these conclusions.

[1] Field Col. Mus. Pub. 36, Geol. Ser., Vol. 1, No. 6.

[2] Anderson, *loc. cit.*, p. 67.

[3] J. P. Smith, "Periodic Migrations between the Asiatic and the American Coasts," *American Journal of Science*, Vol. XVII.

ONTOGENY AND PHYLOGENY

Scaphites nodosus var. **brevis**

Ontogeny.—This particular species or variety has been selected on account of its typical development, and because of the amount of material from which young stages could be worked out.

According to Logan,[1] *Scaphites nodosus* goes through the following stages in arriving at maturity:

1. Anarcestes.
2. Tornoceras.
3. Glyphioceras.
4. Gastrioceras.
5. Paralegoceras.
6. Pronorites.

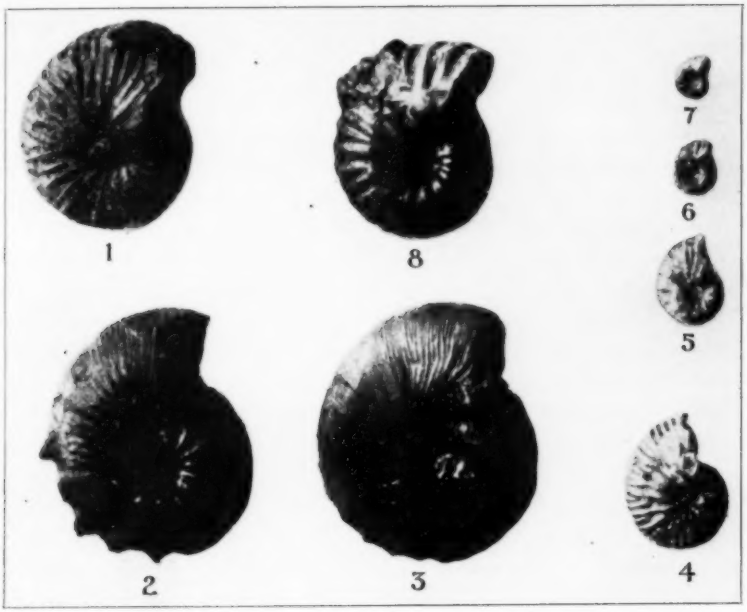
In Fig. 3, the writer has placed, for purposes of comparison, some drawings of the sutures of typical species from the above-mentioned genera. Beyond a rather general similarity to *Glyphioceras*, the writer can see no reasons for correlations. It would be seen, too, from Branco's[2] excellent work on the young stages of ammonites, that many ammonites, and especially of the Jura and Cretaceous, have a Glyphioceran type of suture. It is thought by some that this does not mean kinship with Glyphioceras at all, but that it is a character acquired later, and pushed back by inheritance and acceleration until it is now found in the larva. In support of this, Professor J. P. Smith cites the development of *Pronorites* that possesses a Glyphioceran type of suture in its early stages of development, but which is clearly known not to have come through *Glyphioceras* at all.

In Logan's paper the suture is made the sole basis upon which relationships are based, and this lends itself to much criticism. As Professor Smith and the late Alpheus Hyatt have both respectively claimed, the suture cannot be taken as the sole criterion. Size of whorl, shape of whorl, ornamentation, etc., must be taken into account.

Numbers 9 to 11, Fig. 1, show the protoconch of this species. It is not, in essentials, very much unlike the protoconchs of many

[1] Logan, *loc. cit.*, p. 210.

[2] Branco, *Entwickelungsgeschichte der fossilen Cephalapoden.*



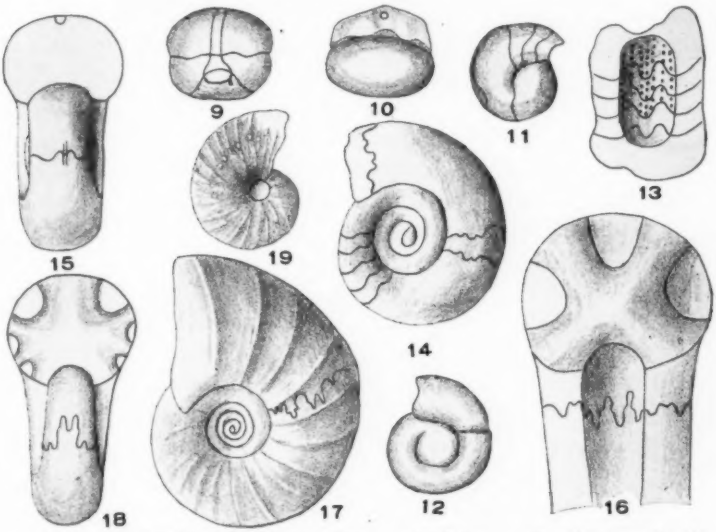


FIG. 1.—1, *Scaphites nodosus* var. *plenus;* natural size. 2, *S. nodosus* var. *brevis;* natural size. 3, *S. nodosus* var. *quadrangularis;* natural size. 4, *S. nodosus* var. *brevis* (Young); natural size. 5, *S. nodosus* var. *brevis* (Young); natural size. 6, *S. nodosus* var. *brevis* (Young); natural size. 7, *S. nodosus* var. *brevis* (Young); natural size. 8, *S. mullananuis.* 9–11, *S. nodosus* var. *brevis* (protoconch); ×30. 12, *S. nodosus* var. *brevis;* D = 1.14mm. 13, *S. nodosus* var. *brevis;* inside of first whorl at D of 66mm; ×30. 14, *S. nodosus* var. *brevis;* 2¾ whorls, D of shell = 2.26mm; ×10. 15, *S. nodosus* var. *brevis;* 2¾ whorls, 1.76mm; 20 D. 16, *S. nodosus* var. *brevis;* internal suture of the above. 17, *S. nodosus* var. *brevis;* 5mm; ×9. 18, *S. nodosus* var. *brevis;* 3¾ whorls; ×4.

Mesozoic ammonites. It is about $\frac{1}{2}^{mm}$ wide and is calcareous, marked with regular rows of small pustules, as in *Lytoceras*, and shows very plainly the siphonal cæcum and siphonal collars pointing forward. What these pustules mean is a matter, more or less, of conjecture; however, it is quite possible that these may be traces of the ornamentation of some ancestor, either *Goniatites strictus*, which in the adult stage shows markings not greatly unlike these, or an ancestor of both. At any rate, they represent a character very remote which has been pushed back now into the embryonic stage. These pustules cease abruptly at a constriction in the shell which occurs at a diameter of 0.66^{mm}, or about one revolution. This is shown in Number 13, Fig. 1.

The protoconch is wider, invariably, than the first coil in all species of *Scaphites* studied during this work, and this is true also in the case of *Baculites* and *Lytoceras*, as will be seen from an examination of the plates in Professor Smith's papers.

The first septum is angustisellate. According to Hyatt, this is called the ananepionic stage, and shows that the animal has in its ontogeny a stage which in the history of the race is that of a nautiloid. (The sutures are shown in Fig. 3.)

With the second septum, which is marked by the development of a siphonal lobe, the animal becomes an Ammonoid. This stage is called the metanepionic or second larval period. Right here may be mentioned one thing that indicates the highly accelerated nature of some characters, and the unequal acceleration that may be found in these later Ammonites In the *Orthoceratidæ* and *Nautilinidae* the siphuncle is central in the former, and just a little distance away from the center in the latter, migrating gradually in the later Nautiloids and Goniatites toward the margin of the coil, until in the ammonites it is marginal. But here, in the very early stages, which are nautilian and goniatitic, we find the siphuncle marginal, and also the collars prosiphonate (these characters could be made out on only the first four septa). In the early cephalopods the collars are retrosiphonate. So we have very great acceleration of some characters compared with others. This in itself makes it quite probable that the sutures are highly modified by acceleration of characters introduced late in the history of the race, and likewise lessens the prob-

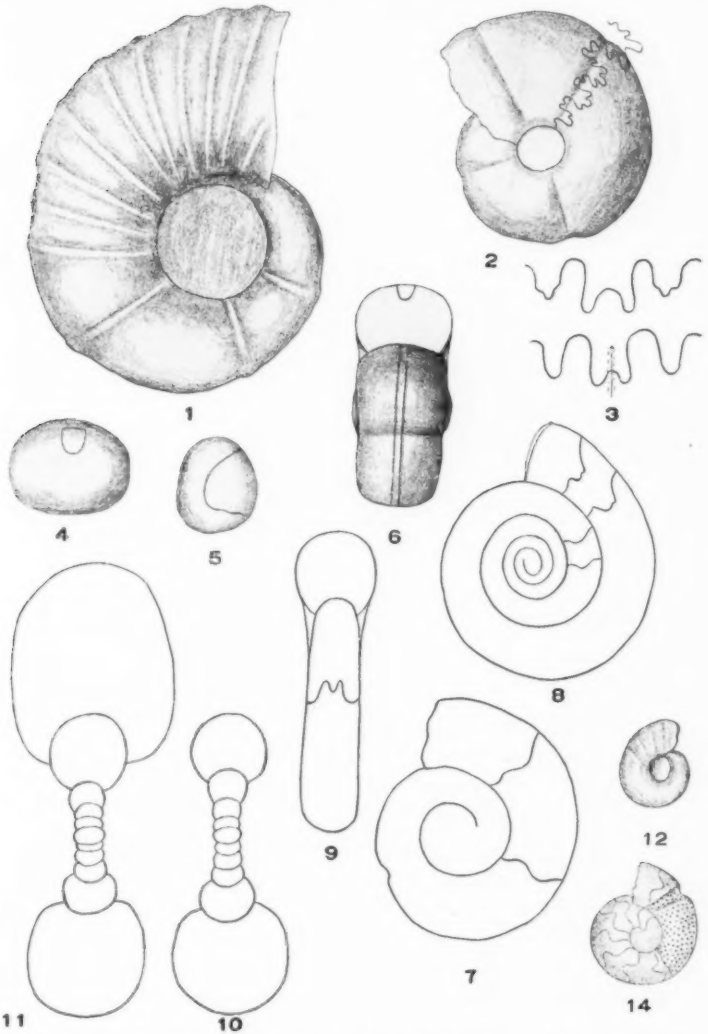


FIG. 2.—1, *Scaphites nodosus* var. *quadrangularis;* ×7. 2 and 3, *Desmoceras hoffmanii;* ×10; 4mm; showing constrictions and development of sutures; 3 represents a much younger stage. 4, *S. condoni* and *inermis* protoconch showing cæcum. 5, Side view of protoconch; ×30. 6, Same at D. of 8mm; ×30. 7, Same at 8mm; ×30. 8, Same at 4mm; ×8. 9, Same at end view; 4mm; ×11. 10, Cross-section of *S. inermis* (half whorl missing). 11, Cross-section of *S. condoni;* ×7. 12, Adult of *S. condoni.* 14, Larval coil of *Baculites chicoënsis.*

ability of their being in close relationships with the ammonoids that Logan cites.

At 0.66^{mm} diameter a constriction was found on one individual (Number 12, Fig. 1), while again specimens were broken back to the protoconch and not a constriction seen. In others it was found recurring several times in the same individual. However, there is no constancy about this feature, as in *Baculites*, *Desmoceras*, and many others (Number 2, Fig. 2). In *Baculites* this is, according to J. P. Smith, a very constant feature, and comes always at the end of the larval coil, i. e., one revolution. In several specimens of *Scaphites condoni* and *S. inermis* this constriction has been noted by the writer at about three-quarters of a revolution from the protoconch.

In the Montana species this is taken by the wrier to be purelyt an individual character, and one likely to be found at almost any point in the development of a phylogerontic group. It means simply that there is a pause now and then in the growth of the animal, as should be expected in the members of a group that we know was then on the decline.

From this point on the shape of the aperture changes rapidly from a crescentic to a more roundish form, due to heightening of the walls, and when the adolescent period is reached, the aperture is almost circular (Number 16, Fig. 1). The adolescent period, in the species studied, has not been found to begin at any constant size. The notching of the first lateral lobe, when it becomes, to use a techincal term, bifid, is assumed to be the beginning of the adolescent period. In one specimen this stage began at a diameter of 1.87^{mm}, in another at 2^{mm}, in a third at 2.26^{mm}, while a fourth continues in a larval state up to 2.48^{mm}, or 2$\frac{1}{2}$ revolutions.

Number 14, Fig. 1, shows a smooth shell of this form and the sutures. The umbilicus is quite wide still, and the shape of the aperture little changed. From this point on, however, the whorl increases rapidly in height and width, and the whole shell becomes thicker. In *S. nodosus* var. *plenus* this growth is very sudden and marked, as will be seen by referring to 7 and 8, Fig. 3.

Some measurements to show the relative growth at the different sizes will doubtless be more useful than a verbal description:

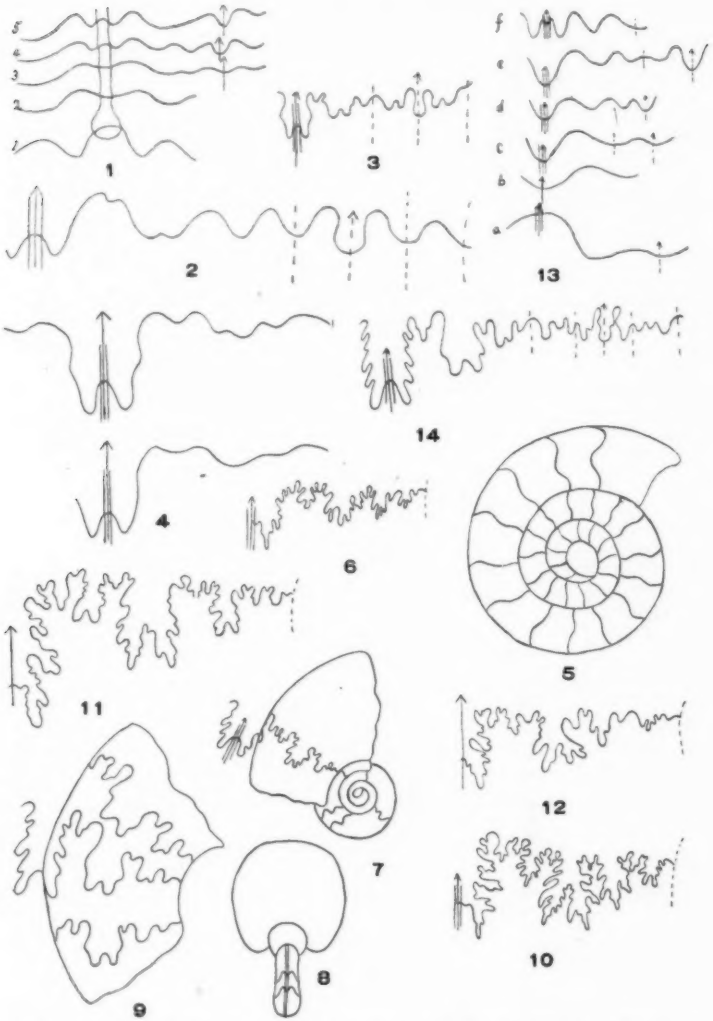


FIG. 3.—1, First five sutures of *S. nodosus* var. *brevis;* ×30. 2, Suture at 2.26mm; ×30. 3, Suture at 4mm; ×10. 4, Suture of *S. nodosus* var. *plenus* at 3mm; 2¾ whorls; ×30. 5, Side view of *S. nodosus brevis* showing sutures 1.76mm; 2¾ whorls 20 D. 6, Adult suture of *S. nodosus brevis;* 28mm; natural size. 7, *S. nodosus plenus* at 6mm; ×7. 8, End view of same. 9, *S. nodosus brevis* at 5mm; ×10. 10, *S. nodosus plenus* adult; natural size. 11, *S. mullananus* adult; ×3. 12, *S. condoni* and adult; ×5. 13, First six sutures of *Glyphioceras diadema* (Branco). 14—Internal suture of *S. nodosus* at same size as that shown in Number 9.

TABLE I[1]

S. nodosus var. *brevis*

	I Proto-conch	II ½ Whorl	III 1 Whorl	IV 1½ Whorls	V 2	VI 2½ Whorls	VII	VIII Adult	IX
	mm	mm	mm	mm	mm	mm	mm	mm	mm
Diameter of shell...	0.40	0.56	0.78	1.04	1.50	2.18	5.00	20.0	5.00
Height of whorl...	0.40	0.26	0.30	0.46	0.60	0.90	2.40	12.0	2.20
Width of whorl....	0.46	0.48	0.50	0.60	0.76	1.12	2.50	13.0	....
Involution.....	....	0.08	0.10	0.14	0.20	0.22	0.42	3.0	0.50
Width of umbilicus	....	....	....	....	0.86	1.22	....	6.0	2.00

From these figures we see that the protoconch is wider than the first coil, and consequently must bulge beyond it (see also Number 15, Fig. 1). The first few whorls, up to the third, are slender, and the umbilicus is correspondingly wider proportionally than in the case of the mature form. The involution in the larval and adolescent stages remains fairly constant, about 1 : 3, i. e., embraced part of the coil to the exposed portion; while in the adult it is 1 : 4 and 1 : 5, becoming less and less until in the old or senile stage the involution becomes negative, i. e., the outer coil begins to leave the inner coil. In both the Pacific province forms and those from the interior an impressed zone at the end of the last body chamber can be seen, which shows clearly that these animals were once coiled throughout, not these particular individuals, but the earlier members of the group.

At the beginning of the adolescent stage the following are the measurements:

	mm
Diameter of shell	2.26
Height of whorl	0.76
Width of whorl	0.84
Involution	0.12

The shell at this stage is absolutely devoid of any marked sculpturing, save the presence of very fine lines of growth running around the coil, parallel to the outline of the aperture. The sutures continue developing gradually. The first change noticed is the development of marginals on the siphonal lobe. Then between the siphonal lobe and the first lateral lobe, and likewise between all the principal lobes, develop smaller secondary lobes. Fig. 3, Number 3, shows the suture at a diameter of 4mm.

[1] VII and IX different individuals.

At a diameter of 5^{mm} the shell is seen for the first time to be sculptured. A slight wrinkling of the surface is first noticed, and this soon becomes well defined costæ, and a little later nodes develop on the ventral shoulders. The costæ are seen to begin on the sides of the coil, running away from the nodes in one direction to the umbilicus, in the other across the venter. The sutures are in number of lobes, and in every way, save in minor, secondary digitations between the lobes, essentially adult. The internal lobes and saddles have changed very much from the types seen in the embryonic stage. These changes are shown in Fig. 3.

The way in which the ribs and nodes begin is interesting, and may be briefly outlined. First, there appears a slight wrinkling along the sides of the whorl; then there is to be seen a swelling along the ventral shoulder line. From these slight protuberances the costæ bifurcate in crossing the venter, but come together at the node on the opposite side. Between these, and later, a short rib develops on the venter, passing round on the sides afterward. In the adult stage more ribs are intercalated in the same manner. On the abnormal body chamber the ribs grow finer, and the nodes or tubercles cease abruptly (Numbers 2 and 3, Fig. 1). *S. nodosus quadrangularis* is the only one in all the forms studied to show nodes on the umbilical shoulders. They are never very prominent, however.

The abnormal body chamber or living-chamber, *anormaler Wohnkammer* of the Germans, marked not only by lack of sutures and diminuation of sculpturing, but in another characteristic, that of leaving the true spiral, is the last living-chamber. In the several species and varieties this is by no means constant. Here are some measurements, diameters at which this chamber begins:

	mm
S. nodosus var. *brevis*	29
S. nodosus var.	30
S. nodosus var.	35
S. nodosus var. *quadrangularis*	37

S. nodosus Owen has a very long body chamber, and, having only one specimen, the writer could not break this off. It begins, though, at about the same diameter as the other varieties. *Scaphites nodosus* var. *plenus* differs in the adult from *brevis*, as will be readily seen in an examination of Numbers 1 and 2, Fig. 1, and Numbers 5

and 10, Fig. 3. The chief differences are the more gibbous form of *plenus*, and minor variations in the serrations and digitations of the suture. Up to the end of the larval stage, however, the two varieties are quite similar in every respect, but, as far as the writer has observed, *plenus* develops no nodes on the umbilicus. Number 8, Fig. 3, shows *plenus* at a diameter of $3\frac{1}{2}^{mm}$ where the great change in size of coil comes in. No specimens of the variety *plenus* were found showing a tendency to uncoil, and, furthermore, no crowding of the septa. It appears to be more normal and less degenerate than any of the forms studied. The young *Scaphites nodosus* Owen is very like, practically indistinguishable from, that of *brevis* and *plenus*. This variety has grown to its extraordinary size due, no doubt, to more favorable conditions. The variety known as *quadrangularis*, whose adult stage has been briefly described at the outset of this paper, differs in the larval stage not materially from the other varieties. In the adolescent and early ephebic stages there is, on the other hand, quite a difference in the ribs, every fifth or sixth one being much more pronounced.

Phylogeny.—In studying the shape of the whorl, number of lobes and saddle of the sutures, and the digitations in each, the umbilicus and sculptures, the writer has been led to the conclusion that the *Scaphites nodosus* group is to be considered as having come from some member of the *Stephanoceratidæ*, or "crown-shaped" ammonites. The writer has compared the young stages of the *Scaphites nodosus* with the young of *Desmoceras hoffmani* and *D. beudanti*, also with *Sonneratia stantoni*, both from the Lower Chico of California and found many general relationships. These similarities are found in (1) the shape of whorl; (2) deep, narrow umbilicus; (3) number and digitation of lobes and saddles in the sutures.

However, there is one marked difference, but one which may be easily accounted for in a way to be explained later, in the lobes of the sutures of *Scaphites* and the forms just mentioned. *Sonneratia* and *Desmoceras* have throughout their development triænidian lobes. The development of such lobes can be seen in Fig. 3, Numbers 2 and 3. This type of suture is the normal type according to Haug.[1]

[1] Emile Haug, "Les Ammonites du Permian et du Trias," extract from the *Bulletin de la Société Géologique de France*, 3d series, Vol. XXII (1894), p. 385.

Sonneratia and *Desmoceras* both change very materially in the ephebic stages, becoming very much flattened through an unusual increase in the height of the whorl. It is found, too, that the same style of suture is characteristic of both *Scaphites* and of the *Stephanoceratidæ*. This can be seen by looking through Sarasin's[1] paper. It is to be noticed, too, that some species of *Desmoceras* have a greater number of lobes than other species, and more than are found in *Scaphites*. In one specimen of *Scaphites nodosus quadrangularis* the writer found one stage, diameter 8mm, that resembled the adult of *Pachydiscus peramplus* Mantell, from the Lower Chalk of England. This is interpreted as being a reminiscence of characters belonging to some ancestor of both *Pachydiscus* and *Scaphites*. This was seen in no other specimen of any of the varieties. The sutures of neither form could be obtained for study, as the specimen of the *Scaphites* did not show it, and the original drawings of this species of *Pachydiscus* were not available.

Pachydiscus wittekindi Schlüter, from the Upper Chalk, also is not greatly unlike some of the early stages of *Scaphites*. Likewise there are reminiscences of *Macrocephalites*. These may be very superficial resemblances, but they are certainly suggestive.

Scaphites inermis and S. condoni

Ontogeny.—These two very small species from the Cretaceous of Oregon and California are both figured in Mr. F. M. Anderson's *Cretaceous Deposits of the Pacific Coast*, already cited above. Their young stages are so nearly alike, up to the very last whorl, that where a number of the two species are thrown into a vial together, it is almost impossible to separate the two. Numbers 10 and 11, Fig. 2, shows the remarkable similarity of the two.

It was extremely difficult to get drawings with the camera lucida of the sutures of most of these specimens, for they are for the most part only casts, and the sutures do not show. The protoconch is not so rounded in these smaller species as in the interior forms, but otherwise is very little different. The cæcal bulb was seen in one case only, and that was not perfectly shown (Number 4, Fig. 2). At

[1] Ch. Sarasin, "Quelques considérations sur les Genres, Hoplites, Sonneratia, Desmoceras, et Puzosia," extract from the *Bulletin de la Société Geologique de la France*, 3d series, Vol. XXV (1897).

.73^{mm}, ½ revolution, there is a constriction which is quite as marked, when seen, as in the young *Baculites* and *Lytoceras*. The presence of pustules could be detected only faintly, not nearly as well marked as in *Scaphites nodosus*. The first lateral saddle is notched at a diameter of 3.4^{mm}, or 3¾ revolutions. At this stage the lobe is bifid, and not trifid, just as in the *nodosus* group, with this difference, that the forms of the *nodosus* group are more accelerated in this respect. There is very little change in either of these species in the adolescent and early ephebic stages, not as much as there is between Meek's varieties of *nodosus*.

It does not appear to the writer, after a study of these forms, that Mr. Anderson found enough differences to warrant him in calling them distinct species. It seems that they differ only in late ephebic stages, and then in a little minor sculpturing. The two are flat, rather thin, with no sculpture until the last coil. It is probable, however, that if these forms had given rise to any progeny, the descendants would have shown that these slight differences had been pushed back and added to until there would be no mistaking even the young.

As these forms were all preserved as casts, the shell itself could not be studied. Whether there was anything distinctive about it or not, resembling any other group, of course remains to be settled.

For comparison the following table has been drawn up:

TABLE II

Scaphites inermis And.

	I Proto-conch mm	II ¼ Whorl mm	III 1 Whorl mm	IV 1¼ Whorls mm	V 2 Whorls mm	VI 2¼ Whorls mm	VII 3 Whorls mm	VIII 3¼ Whorls mm	IX 4 Whorls mm	X 4¼ Whorls mm	XI 5 Whorls mm
Diameter of shell	0.16	0.20	0.28	0.52	0.76	1.24	1.76	2.52	3.52	5.72	8.92
Height of whorl	0.16	0.04	0.08	0.24	0.24	0.48	0.52	0.76	1.00	2.20	3.20
Width of whorl	0.49	0.48	0.48	0.49	0.52	0.56	0.72	1.08	1.60	2.40	3.24
Involution	Too small to measure					0.6	0.14	0.28	0.48	0.20	....
Width of umbilicus	....	...	0.36	....	0.64	....	1.24	....	2.50	. ..	4.50

Ppylogeny.—From a study of the young stages of *Baculites* and *Lytoceras*, both from the material itself and J. P. Smith's[1] papers,

[1] J. P. Smith, "Larval Coil of Baculites," *American Naturalist*, Vol. XXXV, No. 409; "Development of Lytoceras and Phylloceras," *Proceedings of the California Academy of Science*, 3d series, Vol. I, No. 4.

the writer has come to the conclusion that *Baculites* and *Lytoceras*, and these two species of *Scaphites*, had a common ancestor, or *Baculites* and *Scaphites* may have sprung from the *Lytoceratidæ*. Indeed, some are of the opinion that *Baculites* came from the *Lytoceratidæ*, and is a very degenerate descendant from this more normal and progressive family. The likeness of the young stages of *S. condoni* and *inermis* to the young of *Baculites* and *Lytoceras* is more in the general aspect of the shell rather than in any specific characters.

The interior forms of *Scaphites* soon change to forms with narrow, deep umbilici, and come to possess prominent ribs, while the two Pacific province forms do not develop in this manner at all, but remain thin and possessing wide umbilici. (See Numbers 8 and 9, Fig. 2.)

ACCELERATION AND RETARDATION

Logan, in the above-cited article, said that the *Scaphites* from the Interior Sea, *Scaphites nodosus* group, were progressive ammonites. The writer is forced to take issue with Logan on this point. He concludes that they are not progressive, but degenerate forms, and, moreover, forms exhibiting unequal acceleration of certain characters, and hence retarded in the sense that Cope[1] meant. J. P. Smith[2] gives a summary of the work of Hyatt, Cope, and others on the underlying philosophical principles of paleontogeny, and the two laws, the former of which was formulated by Hyatt, and the second by Cope, are explained, so that they will not be stated again in this paper.

In the first place, both of these groups of *Scaphites* are degenerate, and they are considered so on these grounds: (1) in the possession of an abnormal body chamber, they show degeneration or senility; (2) in the dicranidian lobes; (3) in the reduced number of lobes and saddles; (4) in the fact that they have, so far as we know, left no trace of a descendant.

Pompeckj[3] concludes that the possession of the abnormal body chamber marks that particular ammonite as senile, and when the

[1] E. D. Cope, *Origin of the Fittest.*

[2] J. P. Smith, "Comparative Study of Paleontogeny and Phylogeny," *Journal of Geology*, Vol. V (1897), No. 5, p. 508.

[3] J. F. Pompeckj, "Die Ammonoideen mit anormaler Wohnkammer," *Jahreshefte des Vereins für Vaterlandische Naturkunde*, in Würtenberg, 50. Jahrgang (1894), pp. 220–90.

whole species possess it, then the term "phylogerontic" is used to describe the stage. Pompeckj does not agree with Hyatt in saying that this abnormal chamber may appear several times during the growth of the individual, and afterward be absorbed. On the other hand, he asserts that this chamber is always the last chamber.

In one individual only did the writer see anything that looked like a resorption phenomenon, but he is of the opinion that the peculiar swelling around the coil was due to some distortion of the shell. Cases where the individual paused in its growth, forming constrictions and building sutures close together, are quite common in *Scaphites*, but further than these nothing pointing to an abnormal chamber in the young stages similar to that found in the adult or senile stages was found.

All the normal, close-coiled, progressive ammonites, as far as the writer knows, have lobes triænidian. This also is the opinion of Haug, as stated above. On the other hand, *Baculites*, one species of *Lytoceras*, *L. alamedense*, and all the species of *Scaphites* studied show dicranidian lobes. In the matter of number of lobes it will be found, on examination, that many species of *Desmoceras* and many ammonites of the Trias and Jura possess more lobes than are found in the *Scaphites*. This is taken to be another sign of degeneracy.

It seems to the writer that the reduced number of lobes and saddles, and the lessening of the degree of digitation, in many of the varieties of the *Scaphites* may be satisfactorily explained by retardation, i. e., failure to reach the highly developed condition of their ancestors. In the fact, too, that we find simplified sutures and the normal whorls together, and the presence of nodes in the young stages along with other characters that are not signs of senility, we have evidence of retardation. The reminiscenses of *Pachydiscus* and *Macrocephalites*, also, in the young of *S. nodosus quadrangularis* point to unequal acceleration or retardation. From Beecher's[1] work on spines we know that these belong to the gerontic condition, and to find them appearing in the young stages at all shows the working of the law of retardation.

In Number 9, Fig. 3, is illustrated a very interesting point in this

[1] C. A. Beecher, "Origin and Significance of Spines," *American Journal of Science*, Vol. VI (1898).

connection. If retardation be assumed to take place, it is clear that it will be noted first in the case of the lobes and saddles nearest the ventral lobe, for these are the oldest. In this figure the first auxiliary lobe is seen to develop normally into a triænidian lobe, while the first lateral develops in a dicranidian lobe. In time it is quite possible that through unequal acceleration all the lobes will become dicranidian.

VARIATION

In all the varieties and species of *Scaphites* studied the variation is seen to be very pronounced. In the variety *brevis* we find nodes away down in the young stages long before they appear in similar stages of *plenus* and *quadrangularis*. In the Oregon and California species we do not find them until the very last. In the ribs, too, there is seen to be a great diversity. We evidently have to deal with modifications, some of which have been acquired and pushed back in the ontogeny to earlier stages, and others that have been lately assumed. If we could find the progeny of some of these varieties, we might be able to see differences enough to warrant calling them species; for varieties, if given time enough, will undoubtedly produce species.

CONCLUSION

We are of the opinion, then, from this study, that the genus *Scaphites* is in need of revision; that a number of "morphological equivalents," to use Hyatt's expression, have been grouped together as species of one genus; that this genus is polyphyletic, and not monophyletic, as it has been treated heretofore; that both groups of *Scaphites* are degenerate, phylogerontic forms; that the *nodosus* group, from Montana, sprang from some member of the *Sephanoceratidæ*, while the Oregon species probably originated from the *Lytoceratidæ*, or the ancestor of this group.

In the *nodosus* group we have a number of varieties that are on the road to becoming species. In the two so-called species from Oregon and California it is our opinion that we have varieties merely.

Scaphites perrini, found with *S. inermis* and *cononi* by Mr. Anderson, may have come, not from the *Lytoceratidæ*, but from *Stephanoceratidæ*. This is based on the aspect of the whorl, the young stages not being available for study.

These forms, then, sprang from the normal, close-coiled ancestors, but are themselves degenerate, partially uncoiling forms. They may be on the road to a state of complete abnormality, as *Baculites*, *Hamites*, etc., but at present have not gone very far in that direction.

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ERRATUM

To accompany the paper by R. A. Daly on "The Classification of Igneous Intrusive Bodies," *Journal of Geology*, Vol. XIII, p. 485.

NOTE.—Through oversight the "explanations" of the figures in the text were omitted.

EXPLANATIONS OF FIGURES

FIG. 1.—Diagrammatic map of a composite dike in Arran.

(After Judd, *Quarterly Journal of the Geological Society*, London, Vol. XLIX (1893), p. 545.)

1. Country rock (granite).
2. Augite andesite.
3. Quartz-felsite.
4. Pitchstone-porphyry.

The andesite was intruded along a fissure in the granite; then the felsite and porphyry were in succession intruded along the middle plane of the andesite dike.

FIG. 2.—Section of the Moyie Sill, British Columbia, at the crossing of the Moyie River and International Boundary.

Illustrating a body which has the form and relations of a true sill, although the thickness is more than 2,500 feet.

FIG. 3.—Section of a composite sill in the island of Skye.

(After Harker, *Tertiary Igneous Rocks of Skye*, 1904, p. 204.) The stratified Lias was cut by the sill of basalt; a later sill, of granophyre, was intruded along the middle plane of the basic sill. The latter itself may have been double.

FIG. 4.—Section of a composite laccolith.

(After Harker, *op. cit.*, p. 209.) The black is basalt, the white, granophyre. The laccolith cuts heavily bedded lava flows. The maximum thickness of the laccolith is 150 feet.

FIG. 5.—Section of an interformational laccolith.

(After Weed and Pirsson, *Journal of Geology*, Vol. IV (1896), p. 412.) The floor of the porphyry laccolith (in black) is composed of Pre-Cambrian crystalline schists; the cover, of Palæozoic sediments. The length of the section represented is about ten miles.

FIG. 6.—Section of a typical volcanic neck.

(After Geikie, *Ancient Volcanoes of Great Britain*, Vol. II. p. 273.)

FIG. 7.—Diagrammatic map of a Tertiary "chonolith" of rhombenporphyry (crosses).

Cutting intensely folded Palæozoic sediments (broken lines) and Tertiary sandstones and conglomerates (white), occurring on the Kettle River, British Columbia. At its northern end the porphyry disappears under a late Tertiary lava-cap (stippled). The Tertiary sediments are tilted and faulted. The faulting was accompanied, or immediately followed, by the intrusion of the porphyry which field evidence shows to have been injected as a body with a highly irregular form.

FIG. 8.—Diagrammatic map and section of Ascutney Mountain, Vermont.

Illustrating a composite stock, composed of successive intrusions, in stock or boss form, of diorite, syenite, and granite. A small boss of syenite (shown in black) cuts the diorite. These bodies cut crystalline schists, the attitude of which is indicated by the conventional symbol for strike and dip.

FIG. 9.—Map of part of the West Kootenay District, British Columbia.

Illustrating a small batholith of syenite (vertical lining) and the southern edge of the great composite batholith of the district. The latter is made up of the "Nelson granite" (thin, widely spaced, horizontal lines), cut by the younger "Rossland Alkali granite" (more closely set horizontal lines) and by the "Valhalla granite" (heavy horizontal lines). The maximum east-west width of the smaller batholith is fifteen miles.